JOURNAL OF ANATOMY

ORIGINALLY THE JOURNAL OF ANATOMY AND PHYSIOLOGY

CONDUCTED ON BEHALF OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND BY

PROFESSOR EDWARD FAWCETT — UNIVERSITY OF BRISTOL
PROFESSOR J. P. HILL — UNIVERSITY OF LONDON
PROFESSOR ARTHUR ROBINSON — UNIVERSITY OF EDINBURGH
PROFESSOR E. BARCLAY-SMITH — UNIVERSITY OF LONDON
PROFESSOR SIR ARTHUR KEITH — ROYAL COLLEGE OF SURGEONS
LINCOLN'S-INN-FIELDS, LONDON, W.C. 2

VOLUME LVII

PART III

APRIL 1923

Entered at New York Post Office as Second Class Matter

(All Rights reserved)

CAMBRIDGE UNIVERSITY PRESS
C. F. CLAY, MANAGER
LONDON: FETTER LANE, E.C. 4
also
H. K. LEWIS & CO., LTD., 136, GOWER STREET, LONDON, W.C. 1
WHELDON AND WESLEY, LTD., 2–4, ARTHUR ST., NEW OXFORD ST., W.C. 2
CHICAGO: THE UNIVERSITY OF CHICAGO PRESS
(AGENTS FOR THE UNITED STATES AND CANADA)
BOMBAY, CALCUTTA, MADRAS: MACMILLAN & CO., LTD.
TOKYO: THE MARUZEN-KABUSHIKI-KAISHA

Price Ten Shillings net

PRINTED IN GREAT BRITAIN

BIOM

A JOURNAL FOR
OF BIOL

FOUNDED BY W. F. [illegible] K. PEARSON

VOL. XIV. PA[illegible] net (including postage)

CO[illegible]

PAGE

I. A First Study of [illegible] Kind. By C. [illegible] Pennington Student in Craniometry. [illegible] pocket and folding table of measurements . . . 193

II. The Probable Error [illegible] (With two figures in text) . . . 261

III. On the Variable Dimensions [illegible] . . . By KARL PEARSON. (With two diagrams in text) . . . 281

IV. Facial Spasm [illegible] . . . M.D. (With Pedigree in text) . . . 311

V. A Biometric Study [illegible] Length and Weight in a Sample of Herring [illegible] . . . By W. WORCESTER, and RAPHAEL M. NEWMAN . . . 315

VI. A Study in Hæmoglobin [illegible] . . . By G. D. M[illegible] . . . 337

VII. On a certain Sexual Selection [illegible] . . . and 2 diagrams in text) 366

VIII. A Summary of [illegible] Position with [illegible] . . . Illustrations. By ETHEL M. ELDERTON . . . 375

IX. Addendum [illegible] . . . Pearson. (With one plate) . . . 409

X. On an Unusual Case of Bilateral Anomaly . . . Stocks, M.D. (With five plates) . . . 419

Miscellanea: I. On the Correlation [illegible] . . . By KARL PEARSON . . . 418

II. [illegible] . . . PEARSON . . . 418

III. Errata [illegible] . . . 418

IV. Forthcoming [illegible] . . . Notes by J. O. I. . . . 430

Issued by the Biometric La[illegible] London

The University of Chicago Press

A LABORATORY MANUAL FOR COMPARATIVE VERTEBRATE ANATOMY. By L. H. Hyman. [illegible] text-figures. Large Royal 8vo. 12s 6d net

HISTORY AND BIBLIOGRAPHY OF ANATOMIC ILLUSTRATION. By Ludwig Choulant. Translated and [illegible] notes and biography, by Mortimer Frank. With numerous [illegible] 30s net

THE ORIGIN AND DEVELOPMENT OF THE NERVOUS SYSTEM FROM A PHYSIOLOGICAL VIEWPOINT. By Charles Manning Child. With 70 text-figures. [illegible] Science Series

THE BIOLOGY OF TWINS [illegible] By H. H. Newman. With a frontispiece and 55 figures. [illegible] Science Series

SENESCENCE AND REJUVENESCENCE. By C. M. Child. With 201 text-figures. 8vo. 24s net

STUDIES IN THE PALAEOPATHOLOGY OF EGYPT. By Sir Marc A. Ruffer. With a frontispiece, 78 figures and a map. Large Royal 8vo. 37s 6d net

SOLD IN THE BRITISH [illegible] CANADA BY

Cambridge University [illegible] Lane, London, E.C.4

THE ANATOMY OF SO-CALLED DEEP SENSIBILITY

By JOHN S. B. STOPFORD, M.D.
Professor of Anatomy, University of Manchester

At the present time it is customary to divide the loss of sensation, resulting from the section of any nerve containing sensory fibres, into cutaneous (epicritic and protopathic) and deep. This division was suggested by Head as a result of his investigations of patients suffering from division of a peripheral nerve and the observations made in a "Human experiment in nerve division." Our knowledge of deep sensibility is based almost entirely upon a study of the residual sensation found in Head's own hand after section of the radial nerve at its origin from the musculo-spiral, and of the musculo-cutaneous at the point where it perforated the deep fascia, just proximal to its division into the two branches which supply respectively the anterior and posterior aspects of the pre-axial half of the forearm. These nerves were selected because it was believed that, since they are usually described as having a purely cutaneous distribution, a fairly large area of skin would be rendered completely insensitive and yet the sensibility of the subcutaneous tissues would remain undisturbed. From an examination of the residual sensation it was stated that "deep sensibility" was capable of responding to pressure, passive movement of joints and pain caused by excessive pressure. It was also stated that a part endowed only with deep sensibility possessed not only the power of recognising the stimulus but also the power of localising a pressure stimulus with remarkable accuracy. Furthermore it was decided that "the fibres subserving this form of sensation run mainly with the motor nerves, and are not destroyed by division of all the sensory nerves to the skin." From the foregoing it will be realised that the division of sensation into cutaneous and deep is dependent upon the correctness of the view that the radial and cutaneous branches of the musculo-cutaneous are distributed solely to skin. Most anatomical textbooks describe the distribution of the radial as "purely" or "solely" cutaneous, and it seems clear that such descriptions induced Head to select the radial and musculo-cutaneous nerves for his experiment and to believe that the residual sensation could be regarded as unaffected subcutaneous sensibility. My own clinical observations have shown that the radial (1), besides supplying skin, is usually distributed to certain articular structures. From a study of fourteen patients in which the musculo-spiral had been severed, it was found that, although in two the recognition of passive movement was perfect in all the joints, in twelve one or more articulations of the thumb or fingers were affected. Such a study really resolved itself into an investigation of the distribution of

sensory branches from the radial and possibly also from the lower external cutaneous branch of the musculo-spiral to the joints, and showed conclusively that it is customary for one or more joints of the outer digits to be supplied by these cutaneous nerves. This was supported by an investigation of the residual sensation in four patients suffering from division of both the median and ulnar nerves and the examination of a fifth patient, who had had the radial and median nerves severed in the forearm. A careful dissection of nerves, which have unfortunately been described as purely cutaneous, shows that a large proportion of fibres terminate in the subcutaneous tissues. Such a gross method of investigation as dissection does not supply any information about the function of these fibres which can be traced to the deeper tissues, but, from the knowledge obtained from the examination of patients suffering from division of the musculo-spiral nerve, it appears certain that a proportion of them are sensory. Consequently we must not assume that any nerve, of sufficient size to justify its selection for experimental work, is purely cutaneous until it has been so proved. The radial is not normally purely cutaneous in distribution and it seems unlikely that any nerve trunk or branch of sufficient size to deserve a specific name, has an exclusively cutaneous distribution. Consequently we cannot separate anatomically the distribution to cutaneous and subcutaneous structures of any sensory nerve sufficiently large to warrant its use as a source of information with regard to sensation, and therefore any subdivision of sensation into cutaneous and deep must be artificial.

In the course of my studies on sensation the extreme difficulty of determining clinically whether the sensory fibres of a nerve are distributed solely to skin or not became manifest, the chief hindrance arising from the fact that we cannot ascertain for certain whether some aspects of sensation are subserved by fibres terminating in skin, or subcutaneous tissues, or both. This difficulty is particularly well illustrated by localisation, which form of sensation can be shown to be subserved by fibres which terminate cutaneously and subcutaneously. When testing localisation by a method which gave measurable results (2), it was found that after division of the median or ulnar the average error for the localisation of a pressure stimulus on the affected side was about 1·6 cm. to 1·8 cm. whereas on the normal hand it was ·6 cm. This was found to be irrespective of the level of the division of the nerve and therefore it became important to determine if possible whether this was due simply to a loss of cutaneous sensation or was the result of some disturbance of so-called deep sensibility in addition. According to Head, since this marked difference in the power of localisation on the two sides was found even when the nerve had been divided at the wrist without any division of tendons, it ought to have been due simply to a loss of cutaneous fibres, since he maintains that deep sensibility is subserved by fibres which run mainly with motor nerves and is not affected by division of the median or ulnar at the wrist. Several preparations were applied to the unbroken skin in an endeavour to procure an uncomplicated cutaneous anaesthesia, but these proved unsuccessful until

my colleague, Professor R. B. Wild, suggested a 10 per cent. solution of cocaine hydrochloride in chloroform. By applying this solution to a small area of skin, such as the dorsum of a finger, it was practicable to get a satisfactory anaesthesia to the lightest applications of a fine wisp of cotton wool. By measuring the power of localisation of the same part during anaesthesia and after all its effects had passed off, it was found that it was possible to localise with practically the same degree of accuracy under the two conditions. These experiments showed that when the cutaneous fibres were temporarily eliminated, localisation through fibres terminating subcutaneously was for all practical purposes, as accurate as under normal conditions, and therefore the serious errors in localisation discovered after division of the ulnar or median at the wrist must have been due to interference with the subcutaneous sensory fibres. Therefore we may safely assume that in the case of the ulnar or median this aspect of deep sensibility is only in part at any rate subserved by fibres which run mainly with the motor branches and reach the subcutaneous tissues *via* the tendons. These results were verified in a number of patients suffering from division of the median and ulnar, and were found to hold good also in the one case of division of the radial examined. The latter case is particularly important since it shows that, by means of a measurable test for localisation, we can demonstrate that the radial does sometimes at any rate contain fibres which terminate subcutaneously for this form of sensibility, and lends further proof to the contention that the radial is not a purely cutaneous nerve. Therefore two aspects of deep sensibility (recognition of passive movement and localisation) are affected by division of the radial, median or ulnar nerves at the wrist; and of these two forms localisation only can be subserved, and that partially, by fibres which run with the motor nerves and extend along the long tendons to the hand. It seems possible from my own researches and those of others that discrimination may also be served by both cutaneous and subcutaneous systems, but there are even greater technical difficulties to be surmounted before the question can be decided. At first sight the experiment upon Head's own arm appears to establish discrimination as solely dependent upon a cutaneous supply, but it is built on the *assumption* that the radial and terminal branches of the musculo-cutaneous are purely cutaneous nerves, and, since I have found this is not the case normally, the results cannot be accepted as proof that discrimination is only a cutaneous form of sensation. The extent of the anaesthesia, which it was practicable and safe to procure with the cocaine solution, was too small to be of service for the testing of discrimination.

Sensory fibres concerned with two other aspects of deep sensibility, namely, the appreciation of pressure pain and the mere recognition of the contact of pressure, both of which I have investigated, do seem to run with the motor branches. This is well shown by the fact that these forms of sensation are unaffected by section of the median or ulnar at the wrist, whereas division proximal to the origin of branches for the supply of the long flexors

of the fingers and wrist invariably causes an area of complete loss of all forms of sensation.

It is quite clear that the sensory innervation of the deep tissues of the hand and digits is anatomically complex, and consequently it is exceedingly difficult to elucidate the problems of sensation in this region. After it has been realised that the various aspects of sensation now grouped under the term deep sensibility may be dissociated, it becomes possible to unravel the anatomical problem.

The interphalangeal and metacarpo-phalangeal joints receive their sensory supply from the digital branches of the median, ulnar and radial nerves. The localisation of a pressure stimulus is mitigated partly by branches which arise from these three nerves in the palm and on the dorsum of the hand and partly by branches which arise from the main trunks in the forearm, along with the efferent fibres, and so reach the hand by extending along the tendons. As far as it is possible to ascertain by clinical tests, pressure pain and the mere recognition of the contact of pressure are mainly subserved by fibres which run with the motor branches.

REFERENCES

(1) Stopford, J. S. B. "The nerve supply of the interphalangeal and metacarpo-phalangeal joints." *Journ. Anat.* vol. LVI. Part I. 1921.

(2) —— "Tactile Localisation." *Journ. Anat.* vol. LV. Part IV. 1921.

A STUDY OF THE CENTRAL TENDON OF THE DIAPHRAGM

By DUNCAN M. BLAIR, M.B., Ch.B.
Lecturer in Regional Anatomy, University of Glasgow

What Haller designates as "nobilissimus post cor musculus diaphragma" has for many centuries been an object of curious enquiry to human anatomists and physiologists, enquiry at times of so highly speculative a nature as, for example, an attempt to recognise in the diaphragm the seat of the emotions —a statement repeated in a French text-book so recently as just one hundred years ago. Such romancing apart, the diaphragm is certainly in many respects unique among the muscles of the body, and no little part of the interest aroused by it has centred in the nacreous trefoil leaf which we know as its Central Tendon. This piece of tendinous tapestry woven of a complex arrangement of aponeurotic fibres, while undoubtedly showing individual variations in the finer detail of the pattern, yet exhibits a very remarkable uniformity of design in different specimens, and in the first place it is here proposed to present what would appear to be the essential elements in this design.

The material on which the present study is based comprises twelve adult diaphragms taken from anatomy subjects after the adjoining viscera had been removed in the ordinary course of dissection, but with the covering fasciae undisturbed; nine diaphragms removed during post-mortem examinations of still-born full-time foetuses; seven foetuses dissected entire, aged from 2½ months to full-time; and the diaphragms in a young chimpanzee, a Capuchin monkey and a marmoset. For most of the foetal material I am indebted to Dr Cruickshank, Pathologist to the Glasgow Royal Maternity Hospital, and for the comparative material to Sir Arthur Keith, Curator of the Royal College of Surgeons' Museum.

The results obtained in this investigation differ considerably from the published accounts which I have consulted, but the presentment here given would appear to be supported by confirmatory developmental and comparative evidence. Of existing descriptions obtained, undoubtedly the best is that of Bourgery; the better-known account by Poirier would seem to be founded, to a considerable extent, on the earlier work. According to Bourgery, the main elements in the central tendon are two "bandelettes" surrounding the opening for the inferior vena cava. One of these, the posterior semicircular band, passes from the posterior extremity of the right lobe along the whole length of its abdominal surface, sweeps round the vena caval foramen and in front of the oesophageal orifice into the left lobe, at the posterior extremity of which

it ends; horse-shoe shaped, it unites the posterior lobes and forms a protective arch in front of the three great orifices. The other, the antero-posterior oblique band, passes from the right posterior extremity of the central tendon to its left anterior edge; at first on the upper surface above the former band in the right lobe, it forms the internal border of the vena caval opening, separating it from the oesophageal, embraces by two sheets the transverse arch of the first band, and expands into a triangle in the anterior lobe, to the extremity and either side of which it is finally attached.

Poirier, in addition to "fundamental fibres" running obliquely in the lateral lobes and antero-posteriorly in the anterior lobe, describes a "superior bandelette" on the convexity of the tendon, and an "inferior bandelette" on its concavity, corresponding respectively to the oblique antero-posterior and posterior semicircular bandelettes of Bourgery. Poirier's dictum that the central tendon is "the intermediate tendon of a series of digastric muscles" must only be understood in a general sense and cannot be applied to every individual fibre of the tendon.

Dally, in a monograph on the anatomy and physiology of the diaphragm, describes two interlocking U-shaped bands enclosing the vena caval opening between them, the anterior attached by fan-wise expansions to either side of the anterior lobe, its narrow middle portion bounding the vena caval foramen posteriorly, the posterior arising similarly from the extremities of the posterior lobes, with a narrow central portion passing in front of the venous opening.

In all these descriptions, the central tendon is regarded as being founded on two bands, variously described, but always so arranged as to delimit by their intertwining the ellipsoidal foramen for the inferior vena cava. Now this great vein is an asymmetrical structure, derived from the right-hand elements of a series of bi-lateral vessels, and theoretically it would seem strange that a complete transverse body septum such as the diaphragm should be architecturally arranged round a structure developmentally one-sided. In actual fact, the central tendon does exhibit a remarkable symmetry of construction, in many instances even to the extent of reproducing on the left side a miniature replica of the inferior vena caval foramen.

STRUCTURE OF CENTRAL TENDON

The general shape of the central tendon is familiar, consisting of a central intermediate area from which three lobes radiate. Of these, one (anterior lobe) is directed forwards towards the xiphoid process and resembles in form an equilateral triangle, joining the central zone along its base, with the sides slightly curved and the apex blunted. The other two lobes (right and left) are rather tongue-shaped, passing obliquely outwards and backwards on either side, the long axis of each curved with a medial concavity, and the left distinctly narrower than the right. Everywhere surrounded by muscular fibres attached to its periphery, the aponeurosis contains within it the opening for the inferior vena cava, lying in the inner half of the line of junction between

right lobe and central zone. Both surfaces are clothed with a distinct fascial layer—below, this is finer and strips off easily; above, it is denser, more adherent, and firmly attached to the pericardium, which is not structurally attached to the central tendon itself except at the very apex of the anterior lobe. Constructed of a multitude of tendinous fibres running singly, or applied to each other in sheets or flat bundles of varying width, the pattern of the interwoven membrane is simpler and relatively homogeneous in each lobe, but in the intermediate area exhibits a more organised system of primary bands binding together the more peripheral parts. The arrangement shows more clearly on the under surface, where the tendon-margin is also sharply defined. Above, on the other hand, the margin is blurred posteriorly because of

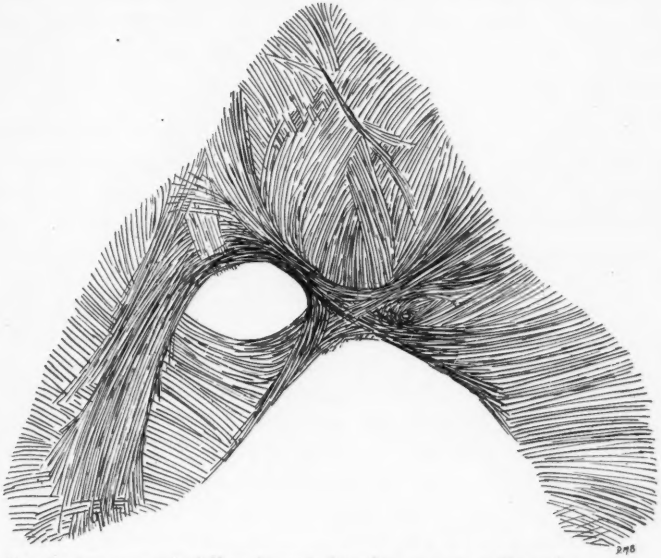


Fig. 1. Arrangement of fibres in central tendon, as seen on the under surface.

a superficial stratum of fine but tough fibres, extending over the muscle fibres, and gradually thinning out as it blends with the covering fascia (figs. 1 and 2).

The simpler arrangements in the lobes may first be described. In the anterior are closely woven fibres passing from the lateral borders and apex, running backwards and inwards in gentle curves, convex forwards, and decussating towards the middle (axial) line of the lobe. Towards the base the fibres run more transversely and towards the apex occasional scattered transverse fibres also occur. The right and left lobes have a common feature, in that they are mainly formed of a sheet of fibres passing transversely to the long axis of the lobe, and running into obvious continuity with muscle fibres on either side; decussation in the axial line of the lobe, if any, is confined to

the tip posteriorly. This (transverse layer) appears clearly on the under aspect, but above it is strengthened and concealed by the stratum of fine fibres previously mentioned. These run longitudinally, but curve in towards the centre of the lobe posteriorly, thus forming a felted decussation. This layer (superior longitudinal), particularly the posterior decussating portion, extends over the muscular part of the diaphragm as a meshwork of fibres which becomes finer and more open towards the periphery. Anteriorly, the longitudinal fibres diverge towards the margins at the "neck" of each lobe, thus exposing on the upper surface the anterior part of the transverse layer; the outwardly-diverging half on each side joins the muscle fibres at the lateral margin where anterior

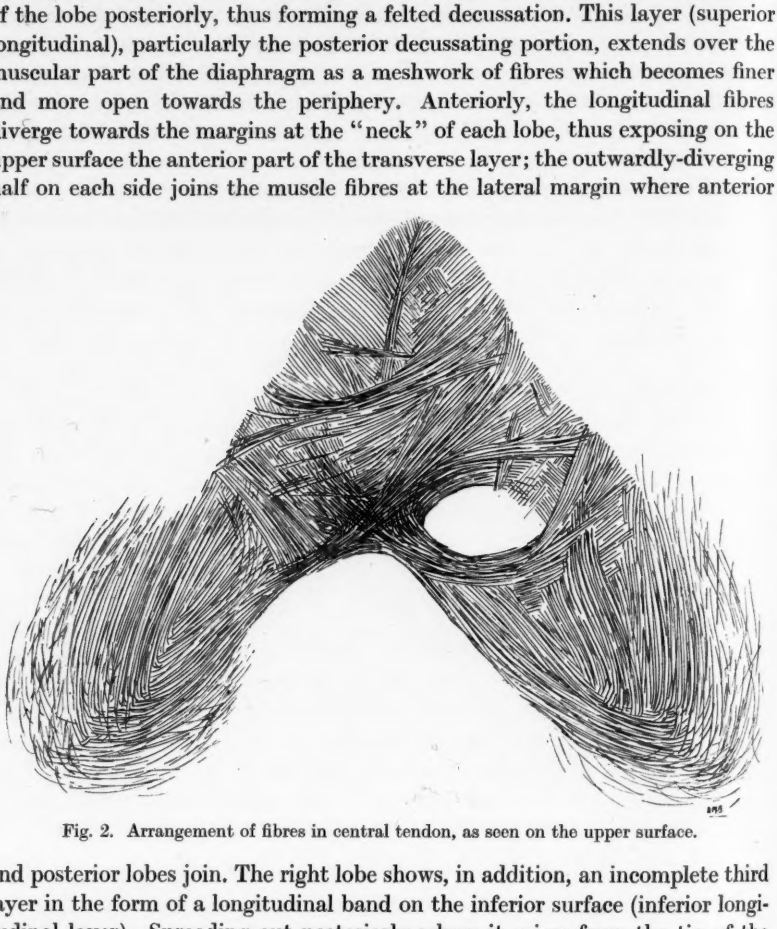


Fig. 2. Arrangement of fibres in central tendon, as seen on the upper surface.

and posterior lobes join. The right lobe shows, in addition, an incomplete third layer in the form of a longitudinal band on the inferior surface (inferior longitudinal layer). Spreading out posteriorly where it arises from the tip of the lobe, its fibres are massed together further forwards as a ribbon-like band sweeping round the outer side of the vena caval opening, antero-lateral to which the outer fibres of the stream join the muscle fibres on the margin of the tendon. It conceals the transverse layer in the middle line of the right lobe and is separated from it just lateral to the venous opening, by the right inferior phrenic vessels passing outwards between the two strata across the neck of the lobe.

Turning now to the central zone, this is found to be occupied by four well-

marked diagonal bands radiating outwards from a central point of decussation like the bars of a St Andrew's cross. This central point appears as a thick node of compressed tendinous strands situated in front of the oesophageal aperture and to the left of the vena caval opening; as the four bands diverge from it towards the various lobes, each expands in fan-wise manner. Regarding them as converging on the central node, each band sends fibres mainly diagonally across the decussation into the opposite band, but also to a lesser extent into each of the adjacent pair. From their relative positions, the bands may be referred to for convenience as right anterior, left anterior, right posterior and left posterior. Each one of the two posterior bands passes backwards and outwards along the inner margin of the corresponding posterior lobe; some fibres then curve outwards across the neck of the lobe and so fall into line with the fibres of the transverse layer, while others pass over or between the transverse fibres and on the upper surface of the tendon run into continuity with the inner half of the superior longitudinal layer. The two anterior bands diverge widely, to become continuous with the more lateral fibres of the anterior lobe and with the muscle fibres on its margin posteriorly and as far backwards as the anterior part of the posterior lobe. Further, each one sends fibres curving backwards into the centre of the corresponding posterior lobe. On the left side this is usually but slightly seen; on the right side, however, a well marked stream of fibres passes backwards round the antero-lateral margin of the caval opening to become continuous with the inner portion of the inferior longitudinal layer. As for the rounded angular intervals between the bands, the anterior is occupied by the more central fibres of the anterior lobe running backwards into the thickness of the central node; the posterior by the muscular fibres of the crura passing up from either side of the oesophageal opening to the posterior part of the central node, which they may slightly overgrow. The right lateral angle forms the foramen for the inferior vena cava, closed laterally by the overlapping of the right anterior and posterior bands (anterior below). The vessel wall is unattached by tendinous fibres to the rounded inner border of the foramen, which is thickened by a characteristic twisted bevelling. In front and behind, a few fine fibres from the margin may decussate on to the coats of the vein, but laterally a well-marked accession of fibres runs from the vessel outwards to the edge of the tendon, strengthening and somewhat obscuring the overlapping already mentioned. Between the left pair of bands is a thinner and therefore slightly depressed area floored by a single layer of fibres, which are continuous with or derived from the adjacent borders of the radiating bands. The floor thus formed by the interweaving of these fibres often exhibits a small perforation transmitting a minute vein.

An examination of foetal diaphragms serves to confirm the arrangements just described. Both in shape and relative size, the central tendon appears to conform to adult proportions. In the youngest foetus dissected (5·5 cm.) the shape is much as in the adult, and the characteristic difference between the two posterior lobes is already distinct. It was noted in this case, too, that the

area of the posterior lobes—as seen from above with the diaphragm in position over the liver—corresponded closely with the portion in contact with the upper surface of the liver, which is moulded on to the vertebral column as a deeply notched crescent with rounded extremities. The concavity of the crescent corresponds exactly to the concave posterior border of the central tendon. In the foetus, the pericardium is readily stripped off the upper surface of the diaphragm, except at the very tip of the anterior lobe, and immediately around the inferior vena cava.

The arrangement of the tendinous strands in the older foetal specimens is the same as in the adult, but the pattern shows with more diagrammatic clearness because of the fewer number of fibres, and the absence of the finer complexities seen in the tougher adult structure. At about six months, only the main fibre-systems are well developed, and a definite tendinous arrangement throughout the whole central tendon is probably not to be seen much earlier than 4½ months. In the earlier specimens, the four central bands are only to be seen as radiating thickenings when the diaphragm is held up against the light, but under a low power of the microscope the typical arrangement of the individual fibres in the bands and the central decussation is clearly to be made out. The more peripheral parts in the youngest diaphragms examined are formed simply of fibrous tissue in which definite tendinous lines are not yet laid down, but even here the central cruciate arrangement is distinct.

The diaphragm of a 6 months old chimpanzee showed a central tendon fully as tough and as thick as in the adult human, although much smaller, and having a very similar arrangement of strands, including the central decussation. In a Capuchin monkey and still more so in a marmoset, the delicate central tendon (distinctly smaller in comparison with the muscular portion than in man) appeared as an almost transparent membrane save for the bars of the central cross which could be clearly seen against the light. With a low-power objective, however, the arrangement of the delicate tendinous fibres could easily be followed out, and showed all the essential elements of the human pattern. In particular, the optic chiasma-like arrangement of the strands in the central decussation was definitely observed in each case. The whole appearance of the central tendon closely resembled that seen in the human foetus at 3–4 months. In all three monkeys, the vena caval opening lay in the right lateral angle of the cross, and the left angle showed a weaker area with, in the Capuchian monkey, a tiny perforation bounded by backward-turning fibres of the left anterior band. An area similarly bounded, but occupied by a diaphanous membrane in which tendinous fibres were absent, was present in the marmoset.

The inferior vena cava, then, is not the central pillar round which the main bands in the tendon turn, but is merely included in one lateral angle of the cruciform ligament which is in turn the mainstay of the central tendon. Further, the foramen for the inferior vena cava is to be regarded as the functionally enlarged right-hand member of a pair of venous foramina of which the left also, as a rule, still exists, but is very much smaller in size. The latter statement will now be considered in more detail.

LEFT VENOUS FORAMEN

In dissecting the adult central tendon, it is not uncommon to find minute veins passing through the tendon by apertures which appear as slit-like intervals between parallel fibres. These are seen chiefly in the posterior part of the anterior lobe, in the angle between the right and left anterior bands. It is to such that Cloquet probably refers when he says: "Au devant de (foramen venae cavae) il n'est pas rare d'en trouver deux ou trois autres, qui traversent obliquement l'épaisseur de l'aponeurose et livrent passage aux veines diaphragmatiques inférieures et sus-hépatiques." Morgagni, in five of his post-mortem records, notes the occurrence of multiple venous foramina in the central tendon, two or three in place of the usual one, but does not always give details of position. One case is evidently that of a subdivision of the usual

Fig. 3. Central portion of central tendon exhibiting a large left venous foramen, as seen from below. (An abnormal muscular slip partly obscures the left posterior band in this specimen.)

caval opening—"tenuissimo quidem interstitio, sed evidentissima divisa." In another, an additional opening immediately in front of the caval foramen apparently transmitted one of the usual hepatic veins which then joined the inferior vena cava above the diaphragm instead of below it, as normally happens.

The foramen to which attention is here directed, however, is almost constant in occurrence, although it varies in size. It is not an artefact or mere slit between parallel fibres, but occurs in a definite position and is definitely marked off in the weaving of the tendon. Such a foramen was seen in ten of the twelve adult diaphragms examined; the size of the largest was 15 × 7 mm., admitting the tip of the little finger (fig. 3); two measured 4 × 3 mm. and the

remainder were more minute. In each case the perforation lay exactly in the angle between the left pair of bands and was circumscribed laterally by a few fibres of the left anterior band curving back into the left lobe. In the better-marked instances, the inner border of the foramen showed the twisting characteristic of the caval opening, with fibres of the left anterior and left posterior bands curving into continuity with each other. At the outer border, the backward-turning fibres of the left anterior band passed on the ventral face of the left posterior fibres, approximating in one case to the formation of an inferior longitudinal layer of the left side. In the full-time foetus this foramen is also usually to be seen, but in the younger diaphragms it is at times

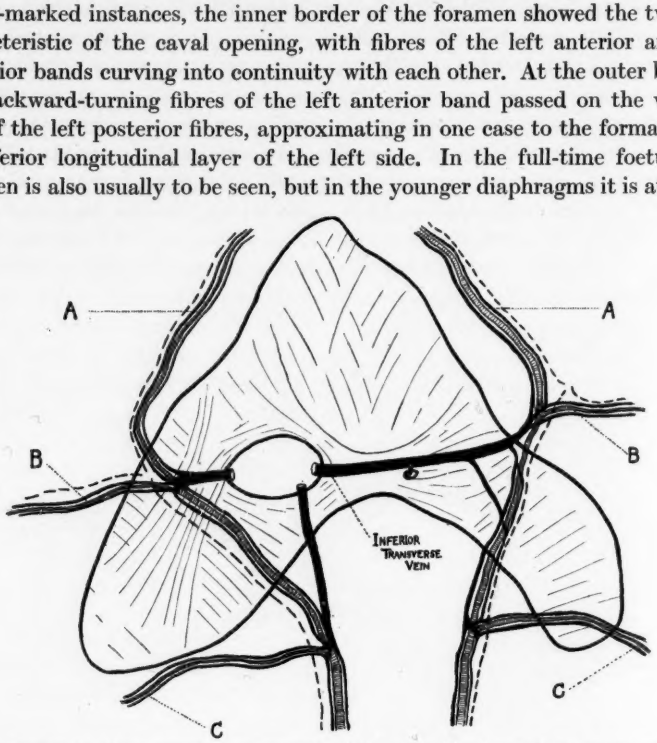


Fig. 4. Diagram to show general arrangement of the main blood-vessels on under surface of central tendon. *A*=anterior; *B*=middle; *C*=posterior divisions of each inferior phrenic artery. (Arteries represented by barred, veins by solid, and nerves by interrupted lines.) N.B. The right inferior longitudinal band is represented as transparent, as the vessels of the right side pass *above* it.

rather difficult to establish beyond doubt either its presence or absence on account of the smallness and delicacy of the parts. In all such cases, however, the left angle of the cross shows a markedly weak area where the tendinous fibres seem to be replaced by a structureless fascia. Sometimes a distinct perforating vein attached by the fascia to the margins of what is at any rate a deficiency in the tendinous structure can be seen to pass through this area. Whenever present, in adult or foetus, this left foramen is traversed by a small vein, to understand the connections of which a somewhat full consideration of the blood vessels of the diaphragm is necessary (fig. 4).

DIAPHRAGMATIC BLOOD VESSELS

On either side, the inferior phrenic artery is to be seen ascending upon the abdominal aspect of the corresponding crus of the diaphragm and then turning obliquely outwards across the posterior lobe of the central tendon at about the junction of its anterior and middle thirds; at this point the vessel on the right side passes deeply to the inferior longitudinal band. The artery is distributed by three main divisions. The first of these (posterior branch) usually arises before the vessel crosses the central tendon and passes backwards and outwards beyond the tip of the posterior lobe. After crossing the tendon, the main artery bifurcates into the middle branch, passing outwards amidst the muscle fibres, and the anterior branch running forward parallel with the lateral border of the anterior lobe of the central tendon. The terminal division on the right side usually occurs just before the vessel escapes from under cover of the inferior longitudinal layer. The phrenic nerve, dividing into terminal branches, pierces the diaphragm close to this final bifurcation of the artery—distinctly in the fleshy part on the left side, sometimes through the outer angle of the caval foramen on the right side, but more usually the right nerve goes through the tendon lateral to this, or even on the musculo-tendinous junction line. One main branch then usually accompanies the anterior branch of the artery, another accompanies the middle arterial branch, and a third, passing backwards along the stem of the inferior phrenic, supplies the crus on its abdominal aspect. Other finer terminal twigs of the nerve run more irregularly.

The three divisions of the inferior phrenic artery are accompanied by venae comites. Those with the anterior and middle divisions unite near the outer margin of the central tendon to form a single channel. This runs transversely into the inferior vena cava—on the right side after a very short course deep to the inferior longitudinal band, while on the left the corresponding vessel forms a large vein (inferior transverse vein) running over the central node of the tendon, and is joined by a twig from the venae comites of the posterior arterial branch. Corresponding to this last vessel a distinct vein on the right side ascends on the right crus to join the posterior aspect of the vena cava just before it pierces the diaphragm.

Where the vessels cross the musculo-tendinous junction line, they are sometimes bound down to the abdominal surface of the diaphragm by slender accessory tendinous strands, and the inferior fascia of the diaphragm also serves to hold the vessels in contact with the central tendon.

The large inferior transverse vein is a prominent and almost invariably constant feature on the under aspect of the intermediate zone of the tendon. As it crosses the left foramen, if such be present, it gives off a small perforating branch which passes through the foramen, and in favourable cases is then seen to join a superior transverse vein (much smaller than the inferior and with less definite connections), running from left to right on the upper surface of the

diaphragm and ultimately ending in the supra-diaphragmatic inferior vena cava. Where the perforating vein joins the superior transverse vein, it is usually joined by a distinct tributary derived from the anterior wall of the oesophagus. In one instance the perforating vein was accompanied by a long, fine branch from the left inferior phrenic artery—in another, by a similar branch from the artery of the right side. This venous circle formed by the two transverse veins both joining the inferior vena cava on the right and being themselves joined by the perforating vein on the left, was traced in four out of ten adult diaphragms in which it was sought for, and in four out of nine full-time foetal specimens. The upper part of the loop is under cover of the pericardium, as the left venous foramen is usually situated just within the margin of the pericardial area of the central tendon.

PERFORATING VEIN

The position of the perforating vein and the similarity in construction of its foramen to that of the inferior vena caval opening suggests that this little vein may be a vestigial left-sided homologue of the inferior vena cava at this level—to be compared with the somewhat analogous correspondence between the oblique vein of Marshall and the superior vena cava. The inferior vena cava as it pierces the diaphragm represents the enlarged upper part of the right vitelline vein, re-constituted, after being broken up in the liver, to form the right hepatic vein. The left vitelline vein in the embryo on its way to the left horn of the sinus venosus is similarly interrupted in the liver, but its upper portion is usually believed to disappear completely at a very early stage, the venae revehentes which would otherwise go to form a left hepatic vein joining the vein of the right side. The occurrence of the perforating vein suggests that the supra-hepatic portion of the left vitelline vein (*i.e.* left hepatic vein) is not obliterated so completely or so early—at any rate, not before the primary construction of the central tendon of the diaphragm is laid down.

The presence of further persisting portions in the track of the original left vitelline stem above or below the diaphragm could not, of course, be traced in the adult or still-born foetal specimens, as the adjacent viscera had been previously removed. A search in the seven foetuses dissected entire, however, revealed in two cases a vein leaving the upper surface of the left lobe of the liver independently, between the layers of the left triangular ligament, having arisen within the liver from a vessel appearing to correspond to the vena hepatica sinistra superior of Mall's nomenclature. In one case (8 cm.) this vessel turned medially to join the inferior vena cava, first communicating with the inferior transverse vein. In another (13·5 cm.) this left hepatic vein joined the inferior transverse vein at right angles just where a distinct perforating vein was given off; a similar arrangement was found on examining a 30 mm. embryo (longitudinal sections) in the Glasgow University collection, although the delicacy of the vessel walls at this stage, and the lack

of injection, rendered accurate tracing of the fine veins involved a somewhat difficult matter. The venous circle already described was identified, and the inferior transverse vein, lateral to the point of origin of the perforating vein, appeared to be joined by two very fine veins which had arisen within the liver from the vena sinistra superior. This connection seemed to be in process of obliteration—in the other two it had so far persisted as to be readily traced by ordinary naked-eye dissection (fig. 5).

In such cases there would appear to be vestigial traces of the upper part of the left vitelline vein issuing from the left lobe of the liver and passing upwards through the diaphragm towards the heart. As for the next and final stage in the course of the vein, from diaphragm to left horn of sinus venosus, no trace was found, unless it be in the more or less constant tributary of the superior transverse vein descending in front of the oesophagus and draining

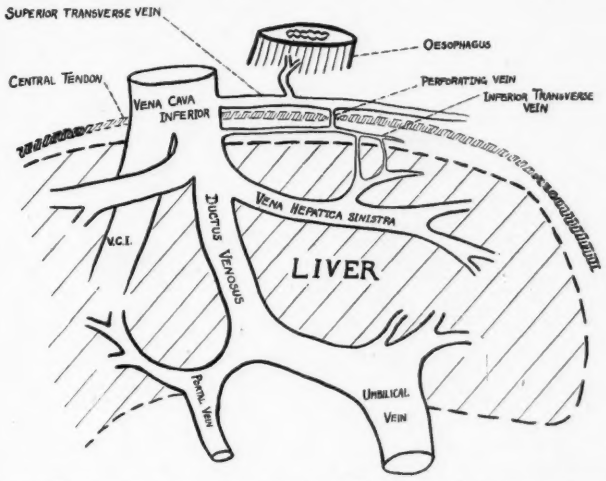


Fig. 5. Diagrammatic reconstruction of conditions found in 30 mm. embryo.

the plexus of veins on the oesophageal wall. This absence of any trace of such a vessel is not surprising when one considers how early and how completely the original relative positions are modified, whereby the left horn of the sinus venosus is removed from all contact with the developing diaphragm and carried upwards as a result of the bending and twisting of the primitive heart tube. It is, however, suggested that vestiges of the supra-hepatic portion of the left vitelline vein are to be recognised in this occasionally occurring vein issuing independently from the left lobe of the liver, and in the much more commonly occurring perforating vein of the diaphragm.

ACCESSORY MUSCULAR SLIPS IN CENTRAL TENDON

In the series of diaphragms examined in the course of this study, abnormal muscular slips were found to occur so frequently in the central tendon as to merit a final note on this point. No examples were found of slips attached to the liver or peritoneum, as have been occasionally noted as diaphragmatic abnormalities; the accessory muscles met with were entirely diaphragmatic in their attachments, lying either on the abdominal aspect of the central tendon or in its thickness, but never on the superficial aspect of its upper surface. They occurred in six out of sixteen foetal diaphragms—in three of these two slips were present, while in another there were no less than four. Five out of twelve adult specimens showed abnormal slips, in two cases out

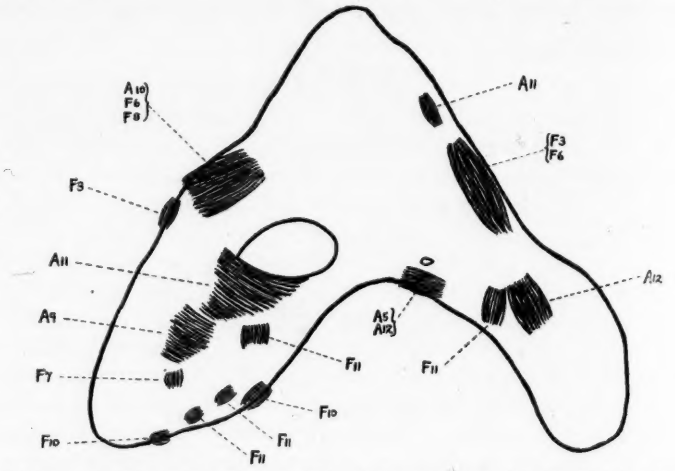


Fig. 6. Diagram to show approximate position of abnormal muscular slips in the series of diaphragms examined. The figures refer to the serial numbers of the specimens in which the particular slips occurred. *A* = adult; *F* = foetal.

of the five two slips being present. The different positions occupied by these slips is indicated in the accompanying diagram (fig. 6).

Most commonly they occurred as flattened fleshy bellies with narrowed extremities attached by tendinous fibres to the central tendon or the covering fascia; in two adult cases they took the form of muscular replacement of portions of the transverse layer of the right lobe—in one of these the intermediate portions of the transverse fibres were replaced by muscle for a distance of 3–4 cms. behind the posterior border of the caval opening. In the Capuchin monkey and comparable with the last case the vena caval foramen was bounded posteriorly by a pointed muscular slip continued inwards from the muscular portion of the diaphragm almost to the inner angle of the foramen. Such occurrences are reminders of what is seen in some other mammals where the

"central tendon" is almost wholly fleshy, as in the pole-cat (Le Double), or entirely so, as in the porpoise (Poirier, Le Double). Le Double also mentions the curious fact that the central tendon in the dromedary encloses a bone, and Morgagni records finding an osseous patch in a human diaphragm.

LITERATURE

Bourgery. *L'Anatomie de l'Homme*, Tome II. Paris, 1834.
Cloquet. *Anatomie de l'Homme*, Tome II. Paris, 1822.
Dally. "The Diaphragm in Man." *St Bart. Hospital Reports*, vol. 44, 1908.
Le Double. *Traité des Variations de Système Musculaire de l'Homme*. Paris, 1987.
Mall. *American Journal of Anatomy*, vol. v. 1906.
Morgagni. *De Sedibus et Causis Morborum*, Epist. v, lx, lxiv, lxvii, lxx. Padua, 1765.
Poirier. *Traité d'Anatomie Humaine*, Tome II. Paris, 1896.

[The illustrations in this article have been published with the aid of a grant from the Carnegie Trust.]

A CASE OF CONGENITAL MALFORMATIONS OF THE INTESTINAL CANAL

By CECIL P. G. WAKELEY, F.R.C.S. (Eng.)

Assistant Surgeon and Teacher of Clinical Surgery, King's College Hospital

Congenital malformations of the intestine giving rise to congenital intestinal obstruction are well known, but this case presents some features which are far from common.

The history of the case was as follows:

The child, a male, was admitted to King's College Hospital two hours after birth with complete absence of the anus. It was the first child and was premature by two weeks. There was no sign of an anus or dimple to mark its position. I made an incision in the perinaeum, but no sign of rectum was found although the wound was explored for a depth of one and a quarter inches from the surface. The wound was stitched up, a laparotomy performed, and a portion of the descending colon was quickly brought to the surface; a small piece of tubing was inserted into the colon and the wound closed. No meconium was passed by the colostomy opening and the child died three days after admission.

On making a careful dissection of the abdomen it was found that the descending colon opened into the prostatic urethra just to the left of the mid-line. A Meckel's diverticulum was present. The stomach was somewhat distended and the duodenum was greatly distended and was larger than the stomach. At the duodeno-jejunal flexure there was a complete septum across the gut through which the smallest probe could not be passed. The rest of the intestine was normal (fig. 1). There were two accessory spleens.

The existence of three or more congenital defects in one subject suggests the question as to their causation. Are all three defects due to a common cause or have they occurred independently? The frequency of multiple congenital abnormalities in single individuals appears to indicate that there is a common cause. Previous cases of congenital abnormalities which have come under my notice, lead me to believe that the common cause is defective nutrition of the embryo in the early stages of growth, leading to arrest of the normal process of development.

The peculiar features of this particular case may all be explained as persistences of early conditions.

(1) The persistence at the site of the septum, of the epithelium, which completely fills the lumen of the gut in the duodeno-jejunal region in embryos of about 6 mm. in length.

(2) Persistence of the intestinal end of the vitello-intestinal duct.

(3) Persistence of the cloacal condition of the embryo which has given rise to a recto-urethral fistula.

The cloacal stage in development is seen to be present in a human embryo

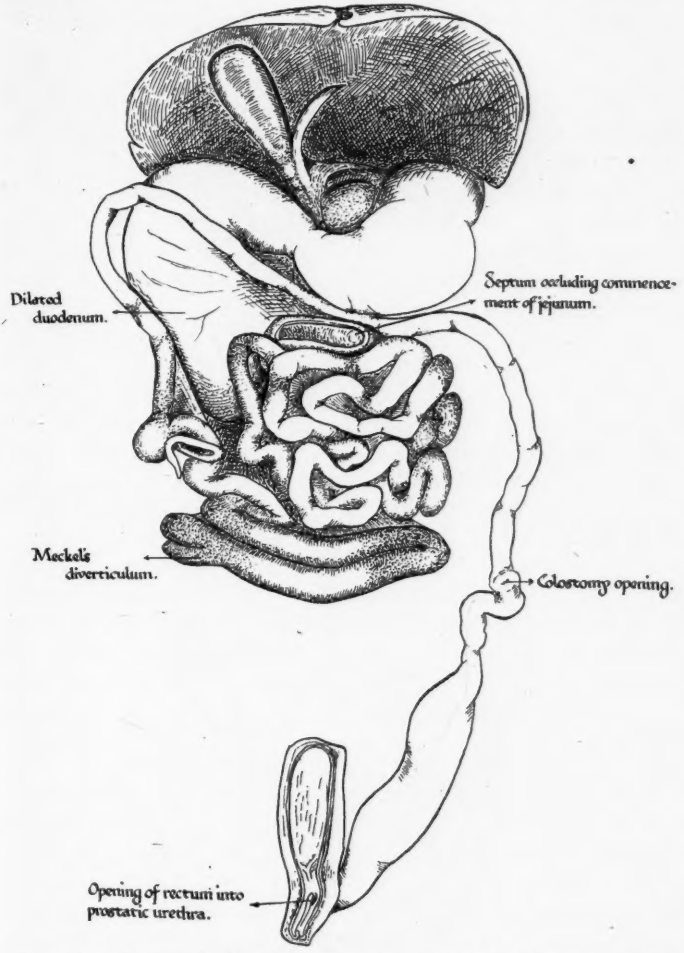


Fig. 1. Front view of the abdominal and pelvic viscera which have been removed from the body. The greatly distended duodenum, which is crossed by the transverse colon, has been opened near its termination in order to show the occluding septum between it and the jejunum. In the lower part of the drawing are seen the colostomy opening, and the opening of the rectum into the prostatic part of the urethra.

of 12 mm. in length and about five weeks old (fig. 2). In a medial sagittal section of a rabbit embryo 15 days old and measuring 13 mm. in length, the

urorectal septum is seen to be in contact with the cloacal membrane thus shutting off the rectum from the pars phallica of the urogenital sinus (fig. 3). A similar stage has been modelled by Professor Hochstetter, in a human embryo

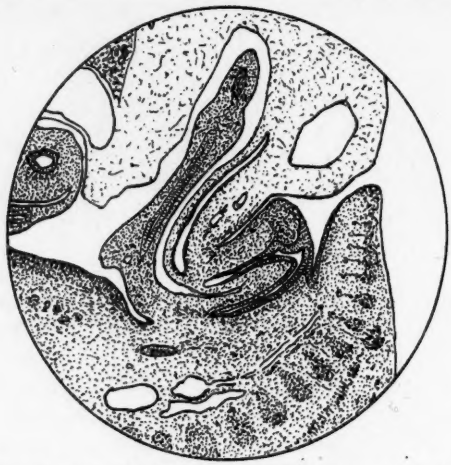


Fig. 2. Sagittal section through the cloacal region of a human embryo, of 12 mm. greatest length, showing the urorectal septum, situated between the rectal and ventral parts of the cloaca. The union of the urorectal septum with the cloacal plate has not yet occurred. The post-anal gut has completely disappeared.

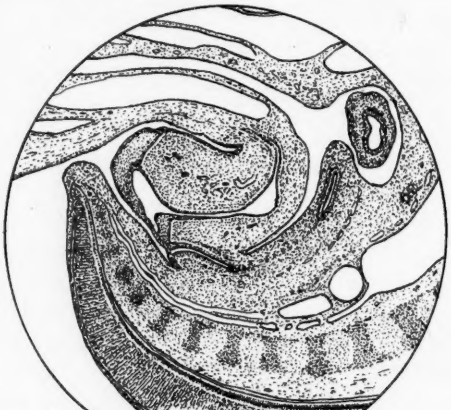


Fig. 3. Sagittal section through the cloacal region of a rabbit embryo, of 15 days, and 13 mm. greatest length, showing the fusion of the urorectal septum with the cloacal plate. No vestiges of the post-anal gut are present.

of 11 mm. At this stage, the lower ends of the Wolffian duct and ureter open by a common orifice in the vesico-urethral part of the ventral cloaca which is

separated from the cloacal membrane by the whole length of the urogenital sinus. In the early stages of development represented by embryos of 4 mm. in length the lower opening of the Wolffian duct opens close to the cloacal membrane and below the level of the intracloacal anus.

It is probable therefore that the defect in the specimen I have described, must have occurred at an early stage when the opening of the Wolffian duct was near the level of the lower margin of the urorectal septum and consists of a failure of the union of the urorectal septum with the cloacal membrane.

The frequent termination of the rectum in the prostatic urethra has been explained by Professor Wood-Jones on the supposition that the "tail-gut," which he postulates grows downwards in the human embryo from the termination of the hind-gut in the cloaca to the proctodaeum, has failed to develop, and that consequently the hind-gut retains its original opening into the cloaca, just below the recto-vesical pouch of the peritoneum. This opening he defines as the intracloacal anus. That part of the intestinal tract which lies below the level of the rectovesical pouch in the human subject ends at the posterior extremity of the ectodermal cloaca, on the "anal slope" of the genital eminence, and does not accompany the notochord into the tail as in the marsupialia, in which there is a long post-anal gut which afterwards becomes cut off from the cloaca, and disappears. Such a post-anal or caudal-gut may be developed as an abnormal condition in the human subject, and may give rise to congenital cysts in the region of the coccyx, or an intestinal fistula in connection with a spinal meningocele and is probably due to persistence of the neurenteric canal. A prolongation of the gut has been described into the ventral part of the penis, and opening under cover of the prepuce beneath the glans. In this deformity the penis is traversed by two channels: (1) the urethra, formed from the "pars phallica" of the urogenital sinus, and (2) the intestinal part most probably formed as a prolongation of the cavity of the hind-gut into the ventral cloacal septum or urethral plate.

In a normal human embryo of 20 mm. greatest length, obtained by operation and in excellent condition, the rectum was found to have already opened on the surface at the posterior end of the ectodermal cloaca. In this specimen no sharp line of demarcation between the epithelium of the anal region and that of the intestine can be detected, and although there is a diminution of calibre below the rectovesical pouch, and at the level of the entrance of the vasa deferentia into the urethra, there is no sharp transition between a segment of the channel which might be described as "caudal-gut" and an upper segment the "hind-gut."

It would appear therefore from the study of this and other specimens of human embryos that the exact position of the junction of the proctodaeum with the rectum, whether at the "white-line" of Hilton or at the edges of the anal valves, or the position of the junction of the "caudal-gut" with the "hind-gut" (or dorsal part of the cloaca) cannot be localised with certainty in the adult.

The question as to whether the rectum is divided by a recto-urethral septum into a ventral (vesico-urethral) and a dorsal (rectal) part, or not, has been definitely settled in the affirmative by the excellent models of the cloacal region made by Keibel, Felix and others in the human subject, and by Dr G. Buchanan and Dr E. A. Fraser in the marsupialia. Cases such as the double channel penis mentioned above however appear to support Professor Wood-Jones' contention with respect to the prolongation of the lumen of the gut as an independent channel which is developed as an outgrowth from the cloaca towards the surface. The channel however is apparently formed in the epithelium of the ventral cloacal septum, and is not a diverticulum of the cloacal wall, similar to the "tail-gut" of the marsupialia.

My best thanks are due to Dr R. J. Gladstone, of King's College, London, for so kindly allowing me to have the use of his embryological material, from which the stages represented have been chosen.

REFERENCES

Buchanan, G. and Fraser, E. A. *Journ. Anat.* LIII. 35.
Felix, W., Keibel and Mall. *Manual of Embryology*, II. 869 *et seq.*
Treves, Sir F. *System of Surgery*, II. 743.
Wood-Jones, F. *Brit. Med. Journ.* II. (1904), 1630.

THE PRIMORDIAL CRANIUM OF *XERUS* (SPINY SQUIRREL) AT THE 17 AND 19 MILLIMETRES STAGES

By Professor FAWCETT
University of Bristol

Two embryos were cut, one of the 17 mm. stage and one of the 19 mm. stage. Only one (of 17 mm. stage) was modelled. The results are of considerable interest. The model shows, amongst other things, four hypoglossal canals, each of which is occupied by a root of the hypoglossal nerve. So far as I know, this is the only mammal in which such a condition has been recorded. The superior semicircular canal is almost isolated by a very deep "fossa subarcuata interna." The lamina parietalis is remarkable in dividing anteriorly into two processes, one inferior and the other superior. The inferior one ends freely, whereas the superior is connected with the ala orbitalis by the orbito parietal commissure. The central stem is interesting because it preserves at this stage the three primitive parts (Pl. I) which seem to be typical of the base of the cranium in mammals at least. The hindmost part is entirely hypochordal. The ala temporalis is perforated by an ali-sphenoidal canal. The stapedial artery perforates the stapes and is of large size. There is a common paraseptal cartilage (fig. 1) which anteriorly is joined with the paries nasi by a lamina transversalis anterior, under which runs the naso-lacrimal duct. There is a lamina transversalis posterior.

General description of the Primordial Cranium

I. *Central stem* (Pls. I, II)

This is divisible into

(1) A pars chordalis.

(2) A lamina polaris (Noordenbos[1]) or lamina hypophyseos (Terry) or pars trabecularis (Fawcett).

(3) A pars interorbito-nasalis.

The pars chordalis is entirely hypochordal from end to end. It commences behind as the anterior boundary of the foramen magnum. It terminates in front at a foramen which is the basicranial fenestra, dividing on each side of this fenestra to unite with the pars polaris. Postero-laterally the pars chordalis is continuous with the ex-occipital cartilage, but the line of continuity is interrupted by the four hypoglossal canals, alluded to previously. Intermedio-laterally the pars chordalis is free and forms the medial boundary of the jugular foramen. Antero-laterally, it is separated by a basicochlear fissure from

[1] Noordenbos. Petrus Camper. 3rd Deel, 1905.

the pars cochlearis of the auditory capsule. Only at its extreme antero-lateral corner is it actually fused with neighbouring parts of the chondro-cranium, i.e. with the pars polaris and pars cochlearis through the medial carotid commissure.

Its intracranial surface is concave from side to side and from end to end. Extracranially it is slightly convex from side to side, but in its cranial half it is comparatively flat and, owing to its thickness in this region, separated by the very deep basi-cochlear fissure from the cochlear capsule.

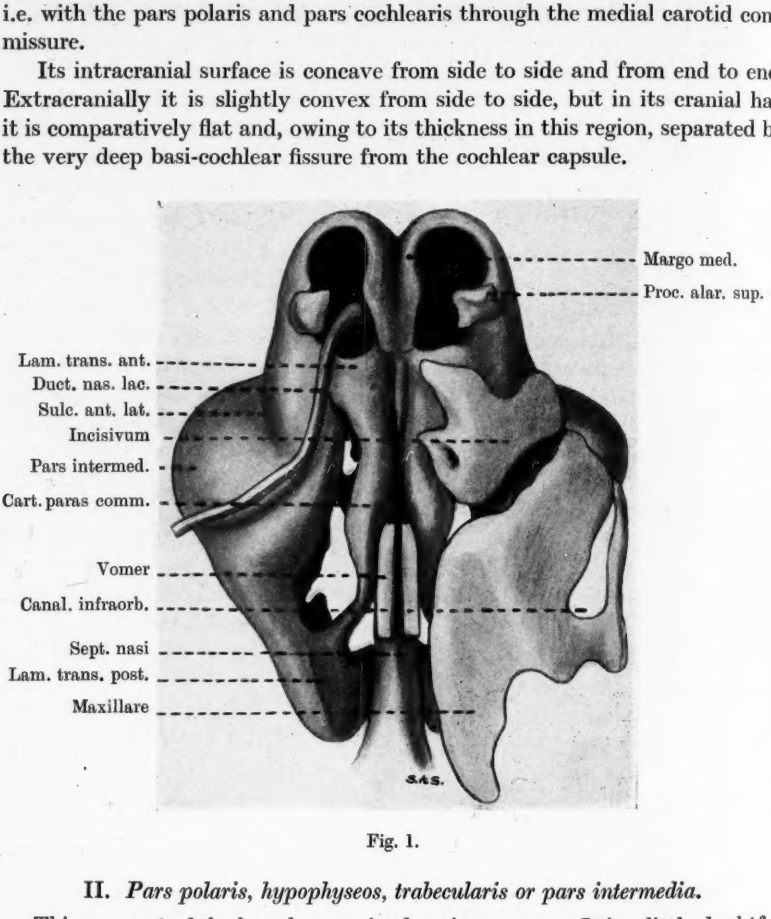


Fig. 1.

II. *Pars polaris, hypophyseos, trabecularis or pars intermedia.*

This segment of the base has received various names. It is a little doubtful whether any one of them is the most desirable. In a sense, the substitution of the name "pars intermedia" would be preferable, in which case the terms pars anterior and pars posterior would be substituted for those used by the author in previous communications. The difficulties arise when one has to describe the processes which connect this segment of the base with neighbouring parts. In general form, this segment, as seen from above or below, is quadrilateral and is comparatively flat from above or below, i.e. intra-cranially or extra-cranially. Its inclination is almost in the same plane as that of the pars posterior (chordalis). It does, however, actually form an angle with this

part but it is a very obtuse angle, about 160°. Its borders are anterior or superior, posterior or inferior and lateral.

The anterior border is overlain by the hinder edge of the lamina hypochiasmatica, from which it is separated by a narrow fissure. Its posterior or inferior border is free about its middle part where it forms the anterior wall of the basicranial fenestra. Lateral to this free part, the posterior border is connected or fused with the pars posterior and with the pars cochlearis, with the latter through the medial carotid commissure. The lateral border from behind forwards consists of three parts, viz. a free part which is the medial wall of the carotid canal; a part which gives off the lateral carotid commissure in common with the processus alaris (the lateral carotid commissure is the alicochlear commissure of authors generally); the most anterior part which is free and forms the medial wall of the superior orbital fissure.

Pars interorbito nasalis (Pls. I, II). This commences behind in a flat plate which is inclined at right angles to the pars intermedia, on whose anterior or superior border it rests, separated from it by a narrow fissure. This plate is equal in width to that of the pars intermedia. In thickness, from above downwards, it is about equal to that again of the pars intermedia. Its antero lateral angles receive the post-optic roots of the alae orbitales and they project freely forwards below the optic foramen to form on each side an ala hypochiasmatica from which the rectus system of muscles takes origin. In front of each ala hypochiasmatica (Pls. I, II) is attached one limb of the pre-optic root of the ala orbitalis. This transversely disposed hypochiasmatical segment of the pars interorbito-nasalis is succeeded by a sagittally directed part which for a short distance forms a part of the inner wall of the orbit and is therefore interorbital, but is very soon placed within the nasal capsule of which it constitutes the septal part. This sudden change from a transversely to a sagittally directed cartilage is very striking and is unusual. The arrangement suggests that of the letter T inverted. Once included within the nasal capsule the nasal septum rises rapidly in height, reaching its maximum height at the level of the crista galli. Beyond this the height gradually diminishes chiefly because the upper edge descends. The lower edge remains practically constant. The upper edge in its hinder part is intracranial and it looks almost backwards and to it is attached in its hinder part the anterior limb of the pre-optic root of the ala orbitalis. Its greater part is free and at this stage unconnected with any lamina cribrosa. The extracranial part lies at the bottom of a slight sulcus, the sulcus dorsalis nasi (Pl. I). Anteriorly the septum appears to bifurcate into two curved plates which bound the anterior nares medially and end below in an outwardly curved free process. The inferior margin of the septum nasi is convex from side to side and is placed first between the posterior cupulae of the nasal capsule and later between the two common paraseptal cartilages. Not far from its anterior extremity the septum is continuous with the paries nasi through the lamina transversalis anterior. In front of this, small lateral projections are given off which correspond with the processus laterales ventrales.

Structures appended to the central stem (Pls. I, II). These are, from behind forwards,

(1) Ex-occipital cartilages.
(2) Auditory capsules.
(3) Processus alares and alae temporales.
(4) Alae orbitales.
(5) Lateral nasal capsules.

Ex-occipital cartilages. These are confluent histologically and anatomically with the postero lateral angles of the pars chordalis of the central stem.

Their junction is only indicated by the presence of the four hypoglossal canals, previously mentioned, which range behind one another in a sagittal direction. The two more anterior foramina are small and about equal in size. The two more posterior foramina are large and are also of about the same size. At the lower margin of the root of the ex-occipital cartilage, a condyle is developed. This extends more on to the chordal plate than is usual at such a stage. The ex-occipital cartilage soon passes underneath the corresponding part of the auditory capsule, and on doing so becomes triangular in section. One surface, the dorsal surface, which lies underneath the auditory capsule is formed on what is usually spoken of as the alar lamina. When traced forwards, this alar lamina projects freely as a processus paracondyloideus. The outer edge of the alar lamina is fused with the auditory capsule for a considerable distance, consequently the recessus supra-alaris which separates this alar process from the auditory capsule does not communicate with the exterior. The inferior, extracranial surface is grooved from side to side forming an area paracondyloidea and this groove is limited laterally partly by the processus paracondyloideus and partly by the crista arcuata occipitalis (Pl. II) which is very well developed. There is an internal surface which helps to form the entrance to the foramen magnum from above. Each ex-occipital is continuous at its posterior extremity with the supra-occipital cartilage or tectum posterius.

Auditory capsule (Pls. III, IV, I, II). The auditory capsule may be described as consisting of a pars canalicularis and a pars cochlearis, and the latter may be further subdivided into cochlear and vestibular segments. The pars canalicularis is much of the usual form found in mammals. It presents for inspection medial, lateral and inferior surfaces. The medial surface is deeply indented by the fossa subarcuata interna which is limited above, behind and below by the superior or anterior semicircular canal. Above and in front of the fossa subarcuata there is a slight eminence which is the eminentia ampullaris anterior or superior. From this eminence springs the outer end of the commissure suprafacialis which is of large size. Additionally there is attached to this region the lamina parietalis by means of the parieto-capsular commissure. The medial surface below and anterior to the fossa subarcuata is formed by the crus commune of the anterior and posterior semicircular canals. This crus is grooved on its medial aspect by the ductus endolymphaticus.

The inferior surface is directed towards the lamina alaris of the ex-occipital cartilage. It is grooved from before backwards forming an inferior arcuate fossa, which is bounded on the lateral side by the prominentia semicircularis posterior. The cartilage in this region is very imperfectly formed—in fact in the anterior part it is absent altogether. This is a common feature in early chondrocranial development. The external or extracranial surface has a roughly triangular outline. The base of the triangle is placed forwards and shows from above downwards the following parts:

A process, the tegmen tympani, which projects forwards over the Malleus cartilage. Below the tegmen tympani there is a shallow fossa incudis and below this a crista parotica to which is attached by dense cellular tissue the styloid process. Below the level of the crista parotica comes the processus mastoideus which is of considerable size and convex in form.

The upper border stretches upwards and downwards to terminate at the cupula. It is formed to a large extent by the anterior or superior semicircular canal and it gives origin in its anterior half or so to the parieto-capsular commissure.

More posteriorly it is free, forming the anterior boundary of a large fissure which is interrupted near its upper end by a very slight attachment of the supra-occipital cartilage to the auditory capsule. The upper segment of the fissure may be called parieto-capsular and the lower occipito-capsular. The cupula is concealed from view externally by the overlap from behind of the supra-occipital cartilage. This overlapping cartilage I have elsewhere termed the operculum of the supra-occipital cartilage. It is not to be confused with the processus opercularis of Talpa, which is a process directed upwards from the auditory capsule itself.

The inferior border is formed by the posterior semicircular canal. It is fused for a considerable part of its extent superficially with the alar lamina of the ex-occipital cartilage. Behind this fusion it is free where it forms the anterior boundary of the occipito-capsular fissure. The actual lateral surface shows behind the crista parotica a swelling which was caused by the lateral semicircular canal—prominentia semicircularis lateralis; above and behind which is a prominentia arcuata, caused by the projection of the fossa arcuata interna.

Pars cochlearis (Pls. I, II). This consists of vestibular and cochlear segments. The vestibular segment shows on its medial surface the internal auditory meatus, which is overhung by the suprafacial commissure, a commissure of large size, projecting from the region of the prominentia ampullaris superior to the base of the cochlear segment of the pars cochlearis. A crista falciformis separates the floor of the meatus into upper and lower parts. The upper part which lies above and external to the lower part shows, more medially, the facial canal for the facial nerve, and more laterally the foramen acusticum superius for the superior division of the vestibular division of the auditory nerve. The lower part is a large, almost circular orifice which is the

foramen acusticum inferius. It is not completed at present by any cribrous plate, but from its postero-inferior quadrant there runs back a foramen singulare to the ampulla of the posterior semicircular canal.

The inferior surface of the vestibular segment is directed downwards and is for the most part occupied by a somewhat jagged opening which is the common orifice of the foramen perilymphaticum and the foramen cochleae.

The lateral surface shows from above downwards, firstly the sulcus facialis and secondly a very large foramen vestibuli, which is partly occupied by the foot piece of the stapes. The large size of this foramen is no doubt due to the imperfect chondrification in this region. Below the foramen vestibuli, quite a prominent prominentia cochleae caused by the first turn of the cochlea, exists.

Cochlear segment. The cochlear segment has a medial surface, a superior surface and a surface which may be described as anterior and wholly extracranial. The medial surface consists of two parts; a part which is directed coronally and is almost flat; and a part in front of this which is directed medially and becomes confluent with the dorsal surface of the pars chordalis of the central stem.

The superior surface is slightly hollowed and is bounded anteriorly by a ridge which, when traced outwards, projects in that direction for a considerable extent as a slightly hooked process arching over the great superficial petrosal nerve. It does not at this stage enclose this nerve in a foramen. The medial end of the ridge is confluent with the lateral carotid commissure. The pars cochlearis, when viewed from above, is seen to be connected with the pars intermedia of the central stem by two commissures, namely medial and lateral carotid commissures.

The anterior surface is wholly extracranial and is the largest of the three surfaces of the cochlear segment. It is separated by a very deep sulcus from the pars chordalis of the central stem. This may be called the basi-cochlear sulcus. At the bottom of this sulcus at the 17 mm. stage, a narrow fissure leading into the cranial cavity is the basi-cochlear fissure. The fissure is obliterated at the 19 mm. stage, but the sulcus retains its original depth. The fissure is bounded posteriorly by a commissure, the chordo-cochlear commissure. About the centre of the anterior surface, the cochlea forms its cupula and from the region of the foramen vestibuli of the vestibular segment, there runs inwards a sulcus septi which corresponds with the septum in the cochlea. The manubrium mallei comes almost into contact with the cochlear segment in this groove.

Processus alaris and ala temporalis (Pls. I, II). The processus alaris, at this stage, has a common origin with the lateral carotid (alicochlear) commissure from the pars intermedia. Ultimately it projects laterally beyond that commissure and reaches the ala temporalis. Postero-inferiorly it fuses with the ala temporalis, but anteriorly and superiorly, it is separated from the ala by a V-like fissure, which is occupied by a wedge-shaped mass of dense cellular

tissue. The pterygoid bone, ending below in a cartilaginous hamulus, lies to the medial side of the terminal part of the processus alaris.

The ala temporalis. As has been mentioned, the ala temporalis is only partially fused with the processus alaris. The ala is at first directed outwards, it is thick from above downwards and comparatively thin from before backwards. The projecting lower end may be regarded as a pterygoid process. Beyond this, the whole ala is directed upwards and outwards, forming the so-called lamina ascendens. At the junction of the ascending with the horizontal part a large ali-sphenoid canal is found perforating the ala from behind forwards. This canal seemed to be occupied by veins and connective tissue. It did not transmit the internal maxillary artery. The upper aspect of the ala is concave from side to side, and the concavity lodges the maxillary division of the fifth nerve. The ala temporalis very nearly reaches the posterior basal angle of the ala orbitalis. It is separated therefrom by the supra-orbital artery. To the medial side of the ala, at its root, is placed the palate bone.

Ala orbitalis (Pls. I, II, III, IV). The ala orbitalis is a large triangular plate, convex from before backwards on its intracranial aspect and correspondingly concave on its orbital surface. Its apical part divides into two branches of which the more posterior is attached to the lateral margin of the lamina hypochiasmatica (trabecularis). This is the taenia metoptica.

The anterior branch, otherwise the taenia preoptica, divides into anterior and posterior rami. The posterior ramus descends with a slightly backward course to reach the antero-lateral angle of the lamina hypochiasmatica. The anterior ramus, much broader than the posterior, fuses with the upper part of the cupula nasi posterior and at the same time with the upper lateral edge of the interorbital septum. Between these two branches and the interorbital septum the foramen prechiasmaticum is situated. This, at the 17 mm. stage, is a long slit. By the 19 mm. stage it has become very considerably reduced in length, owing to the increasing breadth of the two divisions of the pre-optic branch of the ala orbitalis. The posterior basal angle of the ala orbitalis is fused up with the orbito-parietal commissure. The anterior basal angle fuses with the cranial margin of the prominentia frontalis of the nasal capsule. Between the anterior border of the ala orbitalis and the nasal capsule there is a comparatively small orbito-nasal fissure which is oval in form. In the model of the 19 mm. stage this fissure has become subdivided into two small openings, through the anterior of which the nasal nerve is transmitted.

The frontal bone curves around the basal margin of the ala orbitalis and extends along its orbital surface for some distance.

It is not possible to say exactly how the ala orbitalis was originally fused with the lamina trabecularis. Terry[1] described in the mesenchymal stage the ala orbitalis as being connected with the base of the skull, but the posterior root shows an interruption histologically. He describes the roots being formed as processes from the trabecular plate, naming the processes

[1] Terry, "Primordial Cranium of Cat," *Journ. Morphol.* 1917.

pre-optic and met-optic. Further, that these processes blend with corresponding processes of the ala, and that where the met-optic process joins with the post-optic root, there projects a processus paropticus, or processus orbitalis. The squirrel of the 17 mm. stage is too old to draw any conclusions as to the mode of union of the ala orbitalis with the lamina trabecularis. In *Tatusia novemcincta* at the 10 mm. stage, which would seem to correspond with the stage described by Terry of the cat, it would appear that the met-optic root, which alone is recognisable, is connected with the cornu trabeculae, but is not fused with it. The cornu trabeculae gives one the impression of giving off the ala hypochiasmatica which is connected with the rectus system of eye muscles in their earlier stages, but there is no sign of pre- and met-optic processes arising from the trabecular cornu. In Tatusia the term trabecular plate hardly holds, for it consists in the Tatusia of two cylindrical rods which lie side by side below the hinder part of the septum nasi and the interorbital septum. They diverge widely behind and do not form a trabecular plate, nor is that actually formed at the 12 mm. stage; in fact, if one use the term trabecular plate as being synonymous with lamina hypochiasmatica, it can scarcely be said to exist. Appearances suggest that in Tatusia, the pre- and met-optic branches of the apical part of the ala orbitalis grow down towards and fuse with the corresponding cornu[1] trabeculae.

Lateral Structures

These include the ala orbitalis, the parietal plate and the supra-occipital cartilage, together with the commissures which connect these parts together. The ala orbitalis being connected with the central stem, has been described in the group of structures so classified.

The lateral wall of the nasal capsule might be included in this category or in the previous one, but it is, on the whole, more convenient to describe it with the nasal capsule as a whole, and it will only be introduced here to complete what may be alluded to as the cranial brim.

Supra-occipital cartilage. The supra-occipital cartilage unites with its fellow over the cavum cranii to form the tectum cranii posterius. It spreads in a downward direction to unite with the hind end of the ex-occipital cartilage opposite the dorsal prominence of that cartilage (Pls. I, II). It spreads upwards and forwards to unite with the parietal plate in a narrow occipito-parietal commissure; medialwards, as has before been mentioned, it meets its fellow in the middle line forming an unusually deep tectum posterius.

The parietal plate (Pl. III). This plate, otherwise, lamina supra-capsularis, is attached by a broad anteroposterior root to the anterior half of the upper border of the pars canalicularis. It may be described as rising almost vertically with a slight inclination lateralwards. It divides into a posterior part and an anterior part. The posterior part rises up and spreads backwards, becoming confluent with the supra-occipital cartilage, through the occipito-parietal

[1] Cornu is used here to express the hinder divergent extremity of the trabecula.

commissure. The anterior part passes forwards and soon splits into upper and lower branches. The lower branch, which is of considerable depth, comes to an end very soon. The upper branch is continued forwards to the posterior basal angle of the ala orbitalis with which it is fused. To the outer side of both divisions of the parietal plate, lies the parietal bone.

Nasal Capsule (Pls. I, II, III, IV, fig. 1)

The nasal capsule is comparatively short from before backwards, and when viewed from above, presents three segments; a posterior segment which is the pars posterior, an intermediate segment, the pars intermedia and an anterior segment, the pars anterior. These segments are separated by grooves or sulci from each other. Thus the pars posterior is separated from the pars intermedia by the postero-lateral sulcus which corresponds with the main root of attachment of the first primary ethmo-turbinal. The pars intermedia is bounded in front by the sulcus antero-lateralis which separates it from the pars anterior. At least one third, and that the hinder third of the dorsal aspect of the nasal capsule opens at this stage into the cranial cavity by means of two large openings separated by the septum nasi. This is the sub-cerebral part of the capsule. The remainder is pre-cerebral. The sub-cerebral part of the capsule shows, as before said, two large openings into the cranial cavity and there is, as yet, no sign of a lamina cribrosa. The caval orifices, which are separated from one another by the upper margin of the septum nasi, are ovoidal in form. Each is bounded medially by the septum, laterally by the upper margin of the frontal prominence of the pars intermedia and the upper margin of the pars posterior. Posteriorly the opening is bounded by the anterior margin of the tectum nasi posterius, otherwise the tectum cupulae. Each caval orifice is divided into two main bays by the dorsal edge of the first primary ethmo-turbinal, which is directed from behind, forwards and inwards towards a backward projection from the crista galli of the septum. The antero-lateral bay leads into the interior of the frontal recess of the pars intermedia and transmits the antero-lateral bundle of olfactory nerves. The postero-median bay is, in the main, connected with the pars posterior. It transmits the postero-median group of nerves to that region. It is divided into two smaller bays by the projection into it of the second primary ethmo-turbinal.

The orbito-parietal commissure is attached to the middle third of the lateral margin of the caval orifice.

The pre-cerebral part of the nasal capsule. This is made up of the pars intermedia and pars anterior. It is almost symmetrically divided by the sagittally directed sulcus dorsalis nasi which, commencing in front, reaches the whole length of the pars anterior but spreads out and is lost in the pars intermedia. The pre-cerebral part is widest opposite the most anterior part of the pars intermedia. In front of this, it narrows somewhat; then again widens out, and remains of considerable width to its termination. In the pars intermedia, near the middle line and on each side of the middle line is a wide

slit-like opening which is the foramen epiphaniale for transmission of the nasal nerve. Anteriorly the pars anterior terminates on each side in an imperfect cupula anterior.

Lateral aspect of the nasal capsule. The lateral aspect shows the three primary divisions of the capsule separated by the delimiting sulci.

The *pars posterior* narrows behind to form the cupula posterior. Its upper margin is attached to the anterior division of the pre-optic ramus of the ala orbitalis. In front of this attachment, the upper margin of the pars posterior is free, forming the lower boundary of the orbito-nasal fissure. In front of this, it is attached to part of the orbito-parietal commissure. The inferior margin of the pars posterior is free and in its posterior half or so is incurved to form the lamina transversalis posterior. As to whether or no this segment develops independently, as has been shown to be the case in the cat (Terry), in the mole (Noordenbos) and in the calf (own collection), cannot be even surmised from the stage now being described.

Pars intermedia. This forms the deepest part of the lateral wall of the capsule. It juts out between the antero-lateral and postero-lateral sulci. It is readily subdivisible into an upper larger and a lower smaller prominence by a sulcus which coincides with the course of the first part of the naso-lacrimal duct. The frontal prominence gives attachment to the anterior extremity of the orbito-parietal commissure. It corresponds with two recesses in the interior of the nose, viz. the recessus frontalis and the recessus anterior, but the recessus anterior does not give rise to any separate prominence, such as may be seen in many mammals. The inferior prominence or prominentia maxillaris is not so large as the frontal prominence and owes its existence to the recessus maxillaris. From this prominence the inferior oblique muscle of the eyeball takes origin. The prominentia maxillaris when traced forwards spreads out into a triangular flattened area contained between the limbs of bifurcation of the sulcus antero-lateralis. The area is the lamina supra-condialis and it corresponds with the recessus glandularis on the medial aspect. Lateral to it lies the naso-lacrimal duct.

The pars anterior, as seen from the side, is of triangular form, the apex being directed backwards to the medial side of the foramen epiphaniale. Its lower side lies in front of the main upper stem of the sulcus antero-lateralis and the lower of the two branches into which it divides. Towards its anterior end the lower side is fused with the lamina transversalis. Anteriorly, the site of fusion is indicated by a deep sulcus as seen from below, but as viewed from the interior of the nasal capsule corresponds with the atrio-turbinal. The upper side of the pars anterior blends with the tectum nasi at a rounded border. The basal border corresponds for the most part with the lateral margin of the fenestra narina anterior. This, where it joins the lower border in front of the lamina transversalis anterior, is continued into a wing-like process, the processus alaris superior, but above this process the basal border is inrolled to form the margino-turbinale.

Fenestra narina. The fenestra narina is conveniently divisible into a larger dorsal segment, and a smaller ventral segment. The two lie nearly at right angles with one another, the plane of the former being almost coronal with a slight lateral backward tilt, that of the latter being horizontal. The larger upper part has been named by Terry the pars atrialis, and the lower part has been named by him the pars lacrimalis, because it is through the most posterior and external part of this segment that the naso-lacrimal duct enters the nasal cavity. The two segments are almost completely separated from one another by processes which spring from the medial (anterior) and lateral (posterior) margins of the main orifice. The process which springs from the medial wall may be spoken of as the inferior cupular process; the one from the lateral wall is the superior alar process. Although conditions are very much modified in man, owing specially to the shortening of the pars anterior, it is possible that this process may be represented in man by the crus mediale of the alar cartilage. The upper segment may be looked upon as a perforation in a cupula anterior which is unusually complete, and which forms the medial and superior boundaries of the aperture. The lateral boundary is inrolled about its middle to form the margino-turbinal. The lacrimal segment of the fenestra is bounded on its medial side by the processus lateralis ventralis of the septum. Posteriorly it is bounded by the lamina transversalis anterior. Externally it is bounded by the inferior margin of the paries nasi, and in its outermost part is lodged the naso-lacrimal duct.

The solum nasi. The solum nasi is in comparison with that of other mammals, fairly complete. It is represented by the lamina transversalis anterior, and the lamina transversalis posterior, as well as by the common paraseptal cartilage which extends between the two. Of these parts, the least complete, as far at least as chondrification is concerned, is the lamina transversalis posterior. In the solum nasi is the large antero posteriorly elongated fenestra basalis, which is separated from the lacrimal segment of the fenestra narina by the lamina transversalis anterior. The lamina transversalis anterior connects the lower wall of the pars anterior with the septal wall. The actual connection with the septal wall is very slight and one might even describe it as being connected with the septal wall through the hinder end of the processus lateralis ventralis. It is obliquely inclined so that the outer extremity is at a higher level than the inner extremity. The former is also much narrower than the latter, being reduced in width through the presence of an incisura pre-transversalis and an incisura post-transversalis. It is through the incisura pre-transversalis that the lacrimal duct enters the lacrimal segment of the fenestra narina. The inner extremity of the lamina transversalis is much wider than the outer, and that is due to increase in length of the internal posterior basal angle in a backward direction, towards the anterior extremity of the common paraseptal cartilage, with whose medial lamella it is more particularly united. The anterior border of the lamina transversalis is practically straight and transverse. The posterior border is very oblique running

backwards and inwards at about an angle of 45° with the anterior border. Not only does the lamina pass in a backward direction; it also passes downwards, and it fuses at an obtuse angle with the medial lamella of the common paraseptal cartilage. The greater part of the lamina is separated from the septum nasi by a fissure. Only a very narrow connection is formed between the lamina and the septum and that at the antero-internal angle. At the junction of the lamina transversalis with the paries nasi it is crossed by the naso-lacrimal duct which is lodged in a sulcus formed by the upbending of the junctional region. This upbending produces, in the interior of the nose, the atrio-turbinal.

Lamina transversalis posterior. This is the floor of the cupula posterior of the lateral nasal capsule. It is imperfectly chondrified at this stage, but is connected by its front edge with the common paraseptal cartilage. It is entirely free of the septum.

The *common paraseptal cartilage* stretches between the laminae transversales anterior and posterior. It consists of two parts, an anterior which is in the form of a vertically disposed curved plate in whose concavity is lodged the organ of Jacobson, and a posterior which is a cylindrical rod-like structure. At the anterior extremity of the common paraseptal cartilage a very short tunnel is formed by a bridge connecting the extremities of the curved plate around the duct of the organ of Jacobson. The convex side of one paraseptal cartilage almost meets that of the opposite cartilage below the region of the septum. The more posterior cylindrical segment of the common paraseptal cartilage is related to the vomer which lies on its medial aspect. It is this part of the common paraseptal cartilage which is the first to fail to chondrify in those animals in which the solum nasi is less complete than in the one under consideration. The common paraseptal cartilage is separated from the septum in its whole length by the septo-paraseptal fissure.

Medial aspect of the lateral wall of the nasal capsule (fig. 2). This consists, like the lateral aspect, of three parts, namely, pars anterior, pars intermedia and pars posterior. The pars anterior is limited behind by the main limb of the crista semicircularis and by the downward continuation of its anterior limb of bifurcation. Anteriorly, it reaches the lateral margin of the pars atrialis of the fenestra narina.

The pars intermedia is bounded in front by the crista semicircularis, and by the anterior of the two limbs into which it bifurcates, while posteriorly, it is limited by the root of the first primary ethmo-turbinal, but above the level of this root, it communicates with the cavum cranii, by the antero lateral bay of the caval orifice (fenestra olfactoria of Terry). It represents the deepest part of the nasal capsule.

The pars posterior may be described as being bounded in front and above, by the free edge of the first primary ethmo-turbinal. It is bounded behind by the roof, the posterior wall and floor of the cupula nasi. It is characterised by the presence of turbinals. In this particular instance there project into it the second ethmo-turbinal and above that the medial lamella of bifurcation of

the first ethmo-turbinal. The pars posterior is in free communication with the cavum cranii at this stage through the postero medial bay of the fenestra olfactoria. It is the meatus between the second and first ethmo-turbinals in particular which communicates with the caval orifice. No other turbinal is developed in this region at this time. These parts may now be described in greater detail.

The *pars anterior* is divisible into two definite regions, viz. an anterior or atrial region, and a posterior divisible into an upper and a lower channel by means of a ridge which is the naso-turbinal.

The lower channel is continuous posteriorly with the recessus glandularis of the pars intermedia. The upper channel is limited sharply behind by the

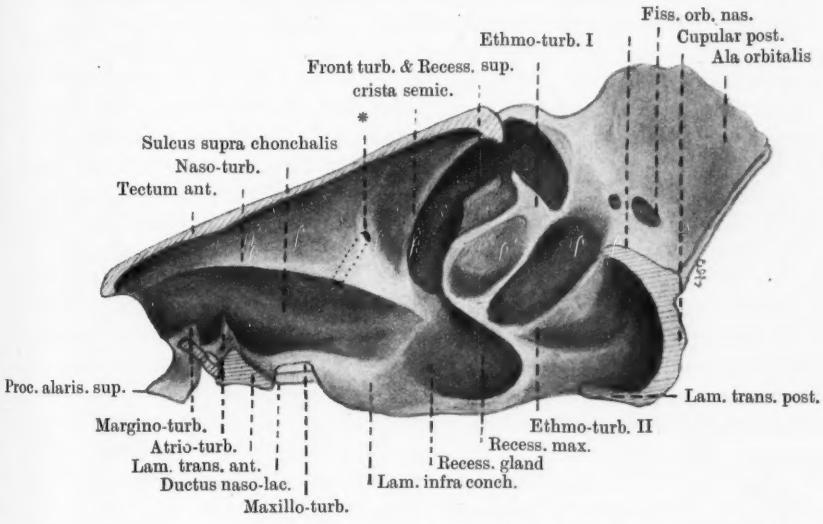


Fig. 2. *Xerus*. Medial aspect of lateral wall of nasal capsule.

stem of the crista semicircularis and into its hinder part opens the foramen epiphaniale. The naso-turbinal is for the most part in continuity with the lateral cartilaginous wall, but towards its hinder end a tunnel passes underneath it and separates it from the lateral wall. Below the naso-turbinal there runs a wide channel which is bounded inferiorly by the atrio-turbinal and by the lamina transversalis anterior. It may be called the supra conchal meatus.

The pars intermedia is deeply recessed between the root of the first primary ethmo-turbinal and the stem of the crista semicircularis. It is especially deep in its upper half or three-quarters. In its lower third or half it becomes shallower in a forward direction, forming a recessus glandularis which anteriorly communicates with the supra conchal meatus, and posteriorly opens into the deeper recessus maxillaris. Perhaps its most anterior inferior part may be

regarded as being formed by the maxillo-turbinal, in front of which there is a deep post-transverse notch. The upper part of the pars intermedia whose floor is formed by the upper half of the first primary ethmo-turbinal is the recessus frontalis, which is complicated by the presence in it of a frontal turbinal. This recess opens into the cavum cranii through the antero-lateral bay of the fenestra olfactoria. The lower part of the upper segment of the pars intermedia projects forwards under cover of the lower part of the stem of the crista semicircularis to form the recessus anterior.

Pars posterior. The pars posterior, which is bounded in front by the free edge of the first primary ethmo-turbinal, is divided into two main parts by the projection of the second primary ethmo-turbinal. That part which lies above and in front of the second primary ethmo-turbinal is in free communication with the postero-median bay of the fenestra olfactoria. It is complicated by a secondary turbinal which is given off from the medial aspect of the first primary ethmo-turbinal. The lower division is practically the cavity of the cupula and it is not in free communication with the cavum cranii as it is separated from it by the roof of the cupula.

Structures forming the Vault and Cranial Brim

The *cranial vault* is formed by a large broad and deep tectum, which runs very straight across from side to side. By means of three processes the tectum was connected laterally with other parts of the cranium. By its lowest process it is fused, without histological distinction with the ex-occipital; by the middle very small process, it is attached to the pars canalicularis of the auditory capsule; by its uppermost process, it is connected through the occipito-parietal commissure with the parietal plate. The middle or occipito-capsular commissure, formed by the middle process just described, divides what would otherwise be a long curved occipito-capsular fissure, into an upper and a lower segment. The lower margin of the tectum shows a wide and fairly deep notch, the incisura superior.

The *cranial brim* is formed in the following way: in front by the anterior margin of the fenestra olfactoria; then by the spheno-ethmoidal commissure, behind which comes the ala orbitalis. This is followed by the orbito-parietal commissure and this in turn by the parietal plate. This latter is continued backwards by the occipito-parietal commissure into the supra-occipital cartilage which forms one half of the tectum posterius. The structures above mentioned constitute one half of the cranial brim.

The *naso-lacrimal duct* (Pl. III) commences by the fusion of two canaliculi opposite the sulcus which, on the outer aspect of the lateral wall of the capsule, divides the prominentia frontalis from the prominentia maxillaris. It continues along the lateral wall near its lower margin occupying the sulcus maxillo-conchalis until it reaches the lamina transversalis anterior; it then passes across this near its junction with the paries nasi, producing a sulcus whose upper convexity projects as the atrio-turbinal. In front of the lamina trans-

versalis anterior the naso-lacrimal duct enters the nose and is confluent with the nasal mucosa.

Visceral skeleton (Pl. III). The visceral skeleton of the first arch is represented by Meckel's cartilage and its two posterior derivatives, the malleus and incus. Meckel's cartilage is long, cylindrical, circular in section in its anterior fourth, and oval in section with the long axis vertical about the middle. Just before it merges with the malleus cartilage it becomes oval. The malleus cartilage is somewhat remarkable in that it is prolonged backwards over the incus into a deep recess under the tegmen tympani. The handle runs parallel with Meckel's cartilage and, like it, is therefore directed inwards. It almost touches the cochlear capsule opposite the sulcus septi. The incus cartilage is, perhaps, in comparison with the malleus cartilage, unduly small. Its processus brevis is not lodged in any fossa incudis, but rather rests against the basal aspect of the pars canalicularis. The processus longus is articulated in the normal way with the head of the stapes cartilage. The stapes cartilage is of much the usual form. It transmits the stapedial artery and is fitted by its foot-piece into the fenestra vestibuli. This fenestra is much larger than the foot-piece of the stapes at this stage.

Cartilage of the second arch. This is represented by a cartilage reaching continuously from the crista parotica to the junction of the corpus hyale with the thyro-hyale. Beyond being cartilaginous in its whole length it calls for no comment. No sign of ossification is present.

The cartilage of the third visceral arch (thyro-hyale) is short and directly connected dorsally with the superior cornu of the thyroid cartilage. Anteriorly it passes without histological differentiation directly into the corpus hyale.

The cartilage of the fourth arch, namely, the thyroid cartilage, is at this stage confluent with its fellow of the opposite side. From the extremities of its posterior border cornua project, namely a superior cornu which is confluent with the posterior end of the thyro-hyal cartilage. Just in front of this posterior border and lying parallel with it foramina are found. There are as many as four in the 17 mm. stage. It is of interest that there should be so many for it puts entirely beyond the range of possibility the supposition that the thyroid cartilage is the result of fusion of two or more visceral arches. The author has long ago pointed out that the thyroid cartilage from Metatheria onwards is derived from the fourth visceral arch.

Towards the middle line the thyroid cartilage presents some peculiarities. There is no sign of a superior median notch. The two alae of the thyroid cartilage are of considerable depth, but at this stage they are not fused for more than the upper half of what would be the medial border in the unfused condition, and from the lower border of the plate formed by the fusion of the two alae there descends a long median process of cartilage which separates for a considerable distance the two alae from one another. Below this process the alae approach each other so closely as to be separated by little more than a fissure, and it is interesting to note that in a later stage, namely 19 mm. the

alae have fused with this projection in such a way as to produce, in the thyroid cartilage, two foramina lying on either side of the middle line.

The cartilage of the fifth arch, namely the cricoid, does not show anything worthy of comment. It is completely ring-like.

The Osseous Skeleton (Pl. IV)

Parietale. The parietale is well ossified as a membrane bone and it covers the upper half or so of the parietal plate. It narrows when traced forwards and finally overlaps the lower posterior angle of the frontale, which it much resembles in general outline.

The *Frontale* is a larger bone than the parietale but like it is broad behind and somewhat narrow in front. It covers the ala orbitalis in part and the spheno-ethmoidal commissure and prominentia frontalis of the pars intermedia of the nasal capsule. An orbital plate is formed but is in a comparatively rudimentary form.

The *Incisivum* consists of facial and alveolar parts. The facial part extends upwards by the side of the pars anterior of the nasal capsule, as well as medialwards under the lamina transversalis anterior and the naso-lacrimal duct. There is no sign of a septo-maxillary bone, nor is there as yet any sign of a paraseptal process (praevomer) of the incisivum.

The *Maxilla* shows a body which lies lateral and inferior to the prominentia maxillaris of the nasal capsule and from which there projects upwards a frontal process parallel with the ascending process of the incisivum. From the body there projects inwards under the nasal capsule a large palatine process. An infraorbital foramen, which is very large and resembles that found in Microtus in being long, narrow and comma shaped, is present. The outer wall of this foramen is formed by a slender bar of bone which stretches from the posterior aspect of the frontal process downwards to the zygomatic bone and is then tied to the body of the maxilla by a slender bar. No sign of accessory cartilage was noted in any part of the maxilla.

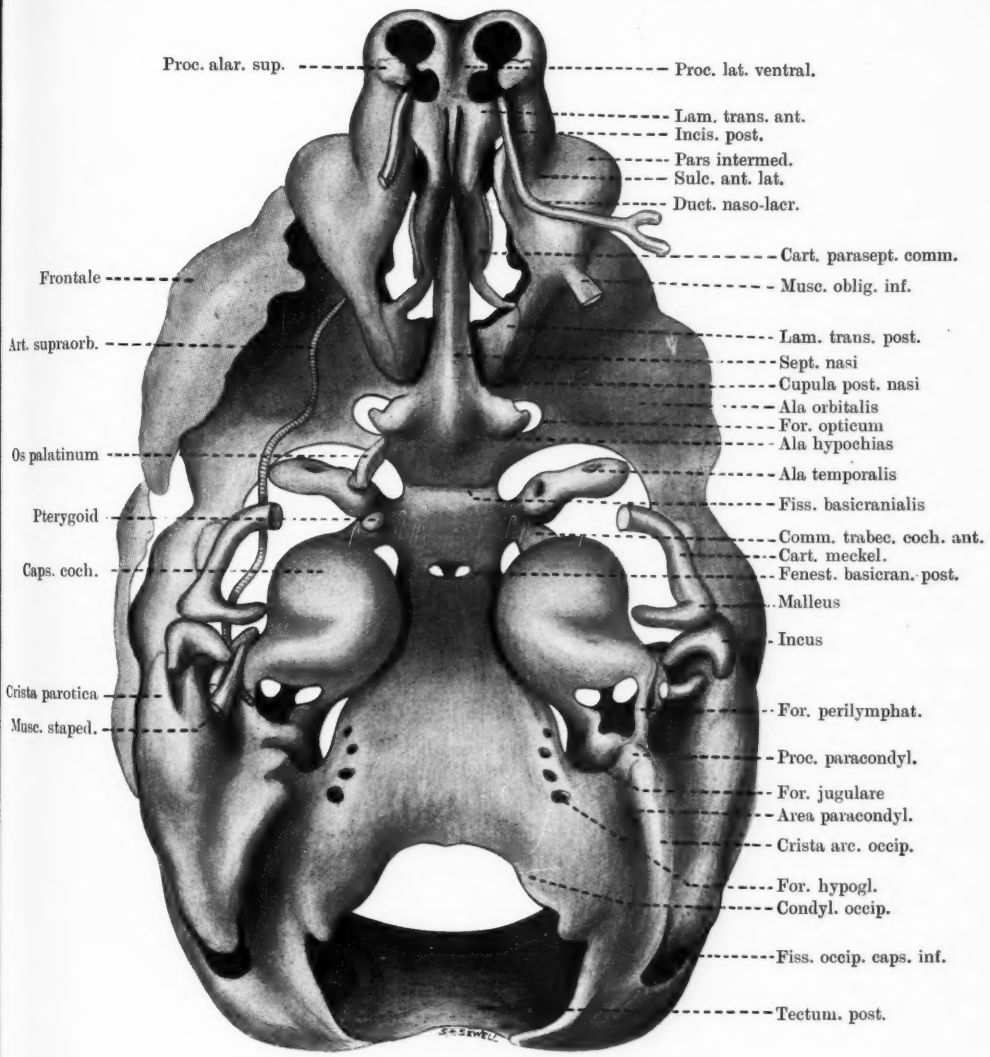
Palatinum. This is a small curved plate-like bone lying behind the maxilla from which it is separated by a considerable interval. It is placed in front of the outer end of the processus alaris of the intermediate region of the central stem.

The *Pterygoid* lies medial to the ala temporalis and behind the palatinum. It practically rests against the cochlear capsule which is of moderate size.

Zygomaticum. This is a slender bone interposed between the maxilla and squamosum. It does not reach the maxilla in front nor is it in contact with the squamosum, but passes below the anterior end of the squamosum.

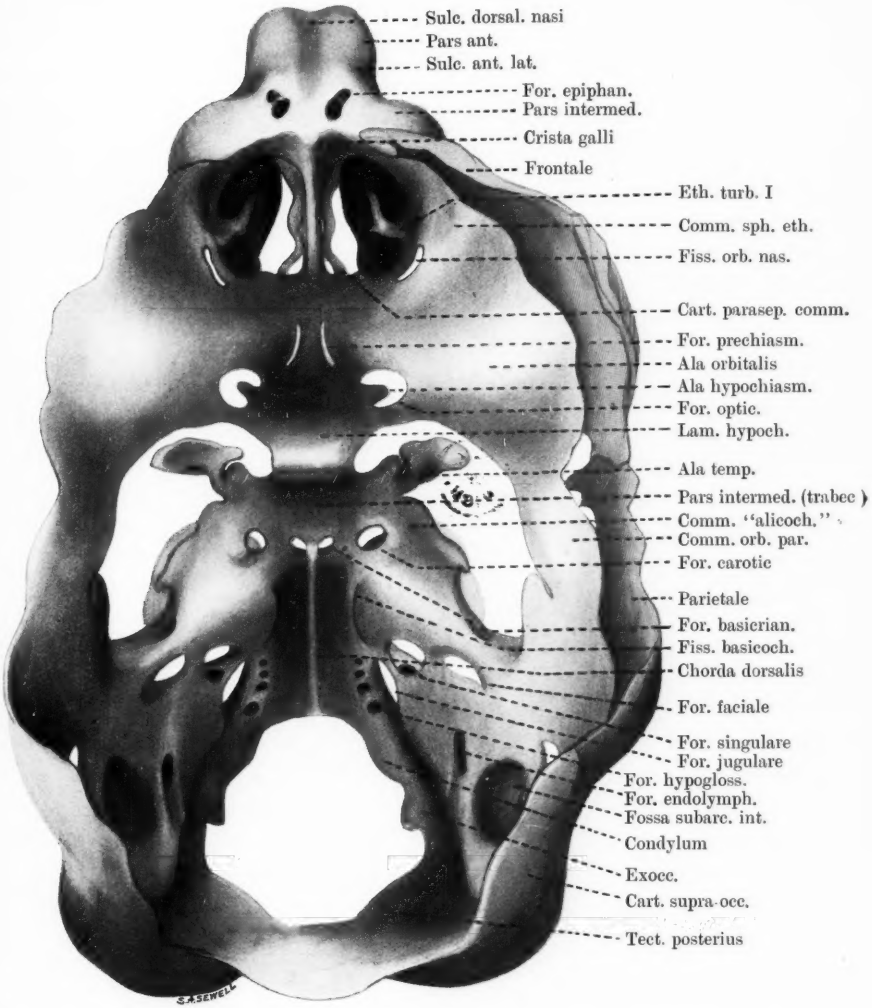
The *Squamosum* in its posterior half or so lies lateral to the malleus cartilage. It has no relation whatever to the incus which is perhaps somewhat unusual. Anteriorly the squamosum bends downwards to lie over the hinder end of the zygomaticum.

The *Mandibula* consists at this stage of a long slab of bone extending from



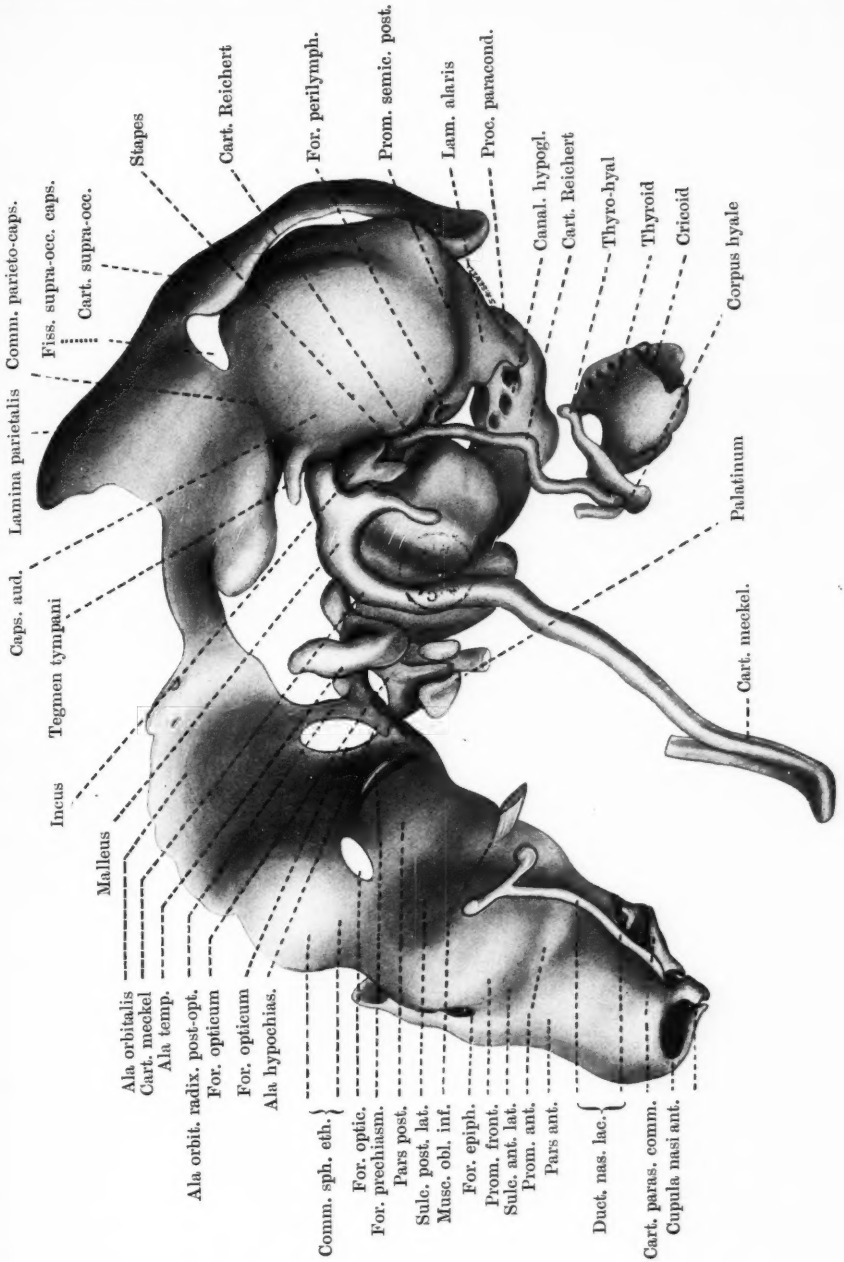
FAWCETT—Primordial Cranium of Xerus.

UNIV. OF MICH.



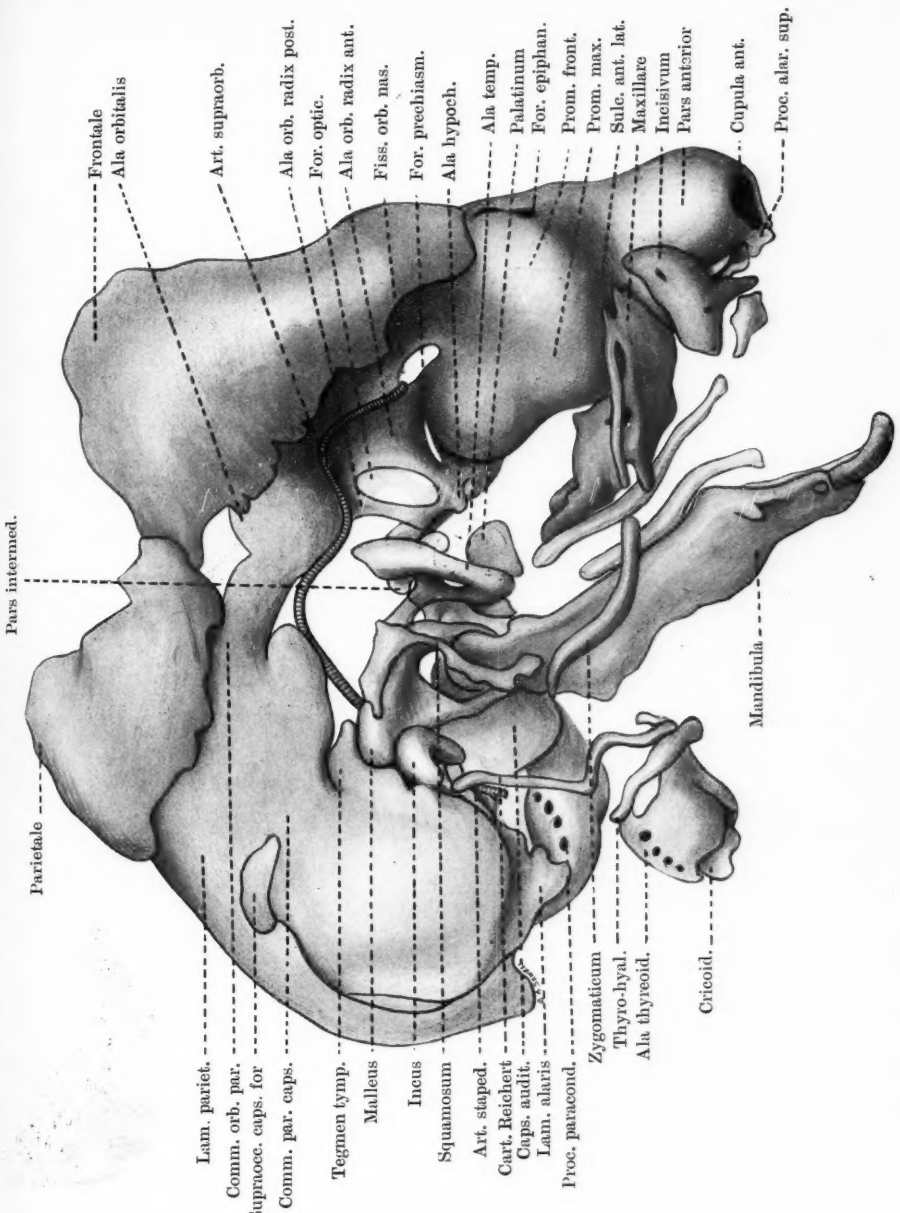
FAWCETT—Primordial Cranium of Xerus.

UNIV. OF MICH.



FAWCETT—PRIMORDIAL CRANIUM OE XERUS.

UNIV. OF MICH.



FAWCETT—PRIMORDIAL CRANIUM OF XERUS.

UNIV. OF MICH.

near the handle of the malleus cartilage to a point not far behind the fused anterior extremities of Meckel's cartilages. The anterior extremity is much narrower than the rest of the bone and does not hide Meckel's cartilage when viewed from the side. A small internal or alveolar wall is present and overhangs Meckel's cartilage. It lies opposite the middle of the mandible. At this early stage neither the lacrimal nasal, tympanic, praevomer nor vomer is ossified but at the 19 mm. stage the vomer is present and is of considerable size. It consists of two separate pieces placed between the cylindrical posterior parts of the common paraseptal cartilages. It may be said in passing that at the 19 mm. stage the palatinum shows the palatine process which is not present at the 17 mm. stage.

ON THE QUADRATE IN CRYPTOBRANCHUS, MENOPOMA, AND HYNOBIUS

By F. H. EDGEWORTH, M.D.

Wiedersheim (1877) stated that in the adult form of *Cryptobranchus japonicus* s. *Megalobatrachus maximus* the quadrate has no basal articulation, but only a single dorsal union, and that the pterygoid process ends freely. Parker (1882) stated that the pedicle of the suspensorium (= basal process of the quadrate) passes into the basis cranii with which it is confluent, that the ascending process is continuous with the alisphenoidal wall, and the otic process with the auditory capsule. The "Epipterygoid" (= remains of the pterygoid process) forms a separate mass of cartilage lying in a groove in the pterygoid bone. The distal end of the "Stapes" was, on one side, confluent with the quadrate, on the other, articulated with it. "The epihyal" was attached to the quadrate further down by ligamentous fibres.

I find in a 37 mm. larva (figs. 1 and 2) that the quadrate has cartilaginous pterygoid, ascending, basal, and otic processes. The pterygoid process passes forwards and its anterior end is confluent with the trabecula and with the inner end of the antorbital process. The ascending process is confluent with the crista trabecula. The otic process is confluent with the auditory capsule. The basal process is directed inwards and backwards and is confluent with the basipterygoid process of the basal plate a little in front of the union of the latter with the auditory capsule. The columella auris passes from the fenestra ovalis on the outer wall of the auditory capsule forwards and slightly outwards and its anterior end is close to the posterior surface of the quadrate.

Wiedersheim stated that in the adult stage of *Menopoma alleghaniense* s. *Cryptobranchus alleghaniensis* the quadrate has an ascending process confluent with the alisphenoid, and a separated pterygoid process. Otic and basal processes are absent. Parker stated that in the adult state the quadrate has three processes, the ascending which passes into the alisphenoidal wall, the pedicle (= basal process) "which passes into the basis cranii above the angle formed by the divergence of the pterygoid and parasphenoid," and the otic which is confluent with the auditory capsule. The pterygoid process is a separate cartilage lying in a groove in the pterygoid bone.

I find that in a 20 mm. larva of Menopoma (fig. 3) the quadrate has no ascending, basal, or otic, processes. It has a long cellular pterygoid process which extends forwards from the quadrate to the trabecula. There is, as yet, no antorbital process. In a larva of 26 mm. (fig. 4) the quadrate has chondrified pterygoid, ascending, and otic, processes. The pterygoid process is confluent with the trabecula. There is no antorbital process. The ascending process is

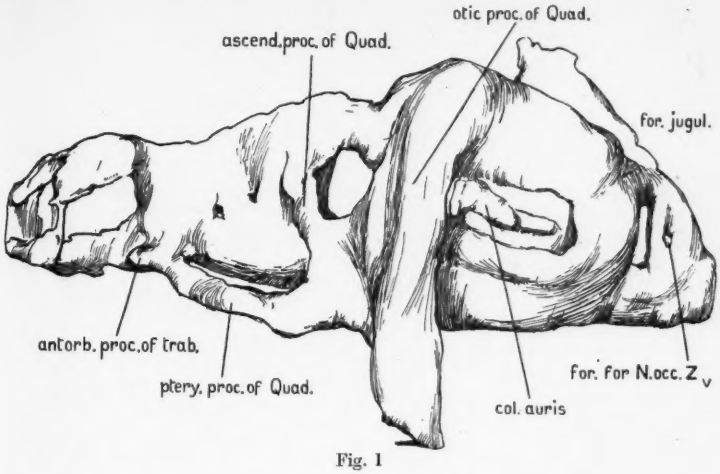


Fig. 1

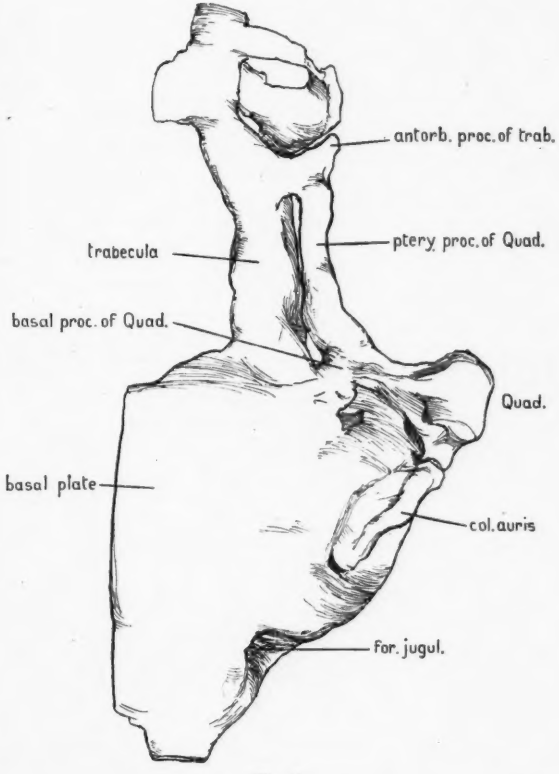


Fig. 2

Figs. 1 and 2. Cryptobranchus, larva 37 mm. Sketches of model of left half of chondrocranium. Fig. 1 from the side; fig. 2 from below.

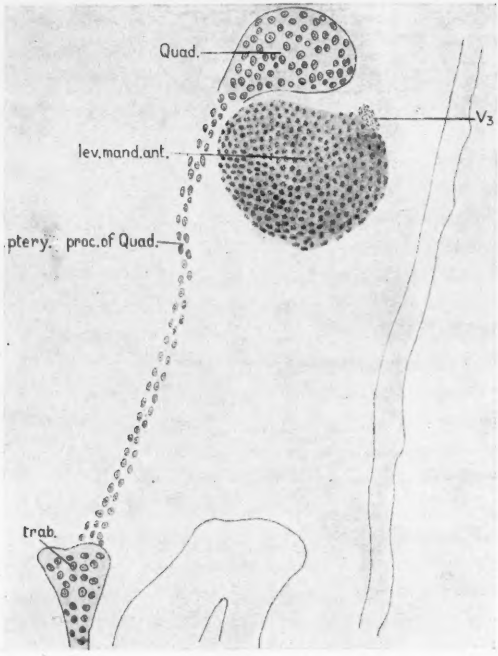


Fig. 3. Menopoma larva 20 mm. Horizontal section.

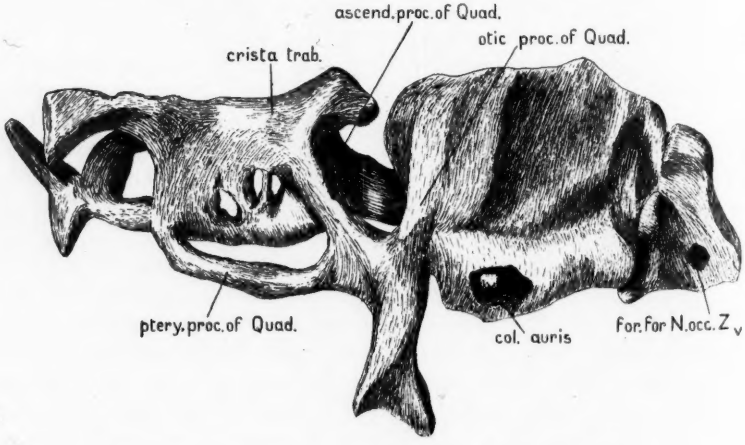


Fig. 4. Menopoma larva 26 mm. Sketch of model, from the side.

confluent with the crista trabeculae, and the otic process with the otic capsule. The crista trabeculae extends backwards beyond the upper end of the ascending process, but does not yet reach the auditory capsule. In a larva of 28 mm. (figs. 5 and 6) the antorbital process is developed; its inner part is confluent

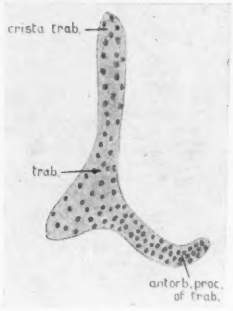


Fig. 5

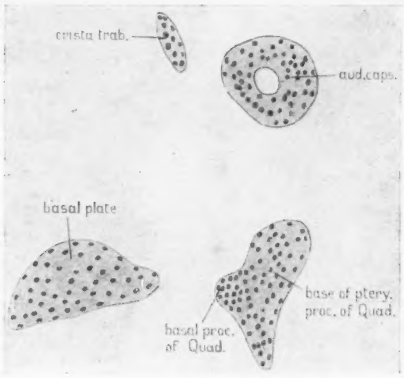


Fig. 6

Figs. 5 and 6. Menopoma larva 28 mm Transverse sections, fig. 5 through the antorbital process; fig. 6 through the quadrate and the inner end of its basal process.

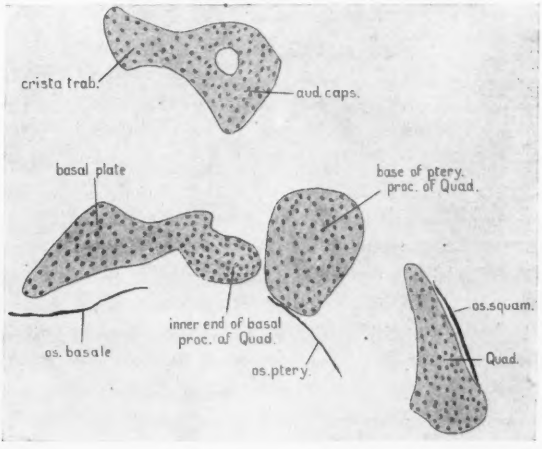


Fig. 7. Menopoma larva 40 mm. Transverse section through quadrate and the union of its basal process with the basal plate.

with the trabecula and with the inner end of the pterygoid process of the quadrate from which it extends antero-laterally. There is a slight basal process projecting from the base of the pterygoid process of the quadrate. The posterior end of the crista trabeculae is confluent with the anterior part

of the auditory capsule. In a 40 mm. larva (fig. 7) the basal process has extended inwards and backwards and its extremity is confluent with the outer part of the basal plate just in front of the junction of the latter with the auditory capsule. There is no basipterygoid process of the basal plate. The columella auris passes forwards and outwards from the fenestra ovalis, its anterior end is in contact with the squamous bone.

Wiedersheim stated that in the adult stage of *Hynobius naevius* s. *Ellipsoglossa naevia* a process of the quadrate passes towards and articulates with the basal surface of the prootic region. He did not mention the existence of

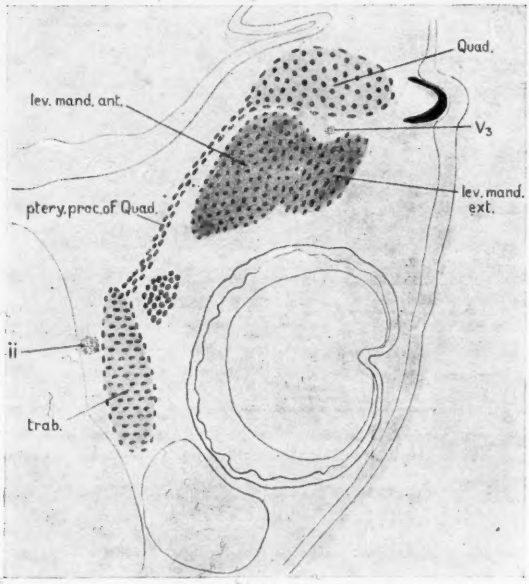


Fig. 8. Hynobius larva 13 mm. Horizontal section.

ascending, otic, or pterygoid processes, but in his figure depicts a pterygoid process which ends freely.

I find that in a 13 mm. larva of *Hynobius nebulosus* s. *Ellipsoglossa nebulosa* (fig. 8) the quadrate has ascending, otic and pterygoid processes. The ascending process is confluent with the crista trabeculae, and the otic process with the auditory capsule. The pterygoid process is wholly cellular; its anterior end is continuous with the trabecula. The antorbital process has not yet developed. In a larva of 20 mm. (figs. 9, 10 and 11) the ascending process is confluent with the crista trabeculae and the otic process with the auditory capsule. The pterygoid process is wholly chondrified; its anterior end is confluent with the trabecula and with the inner end of the antorbital process which has now

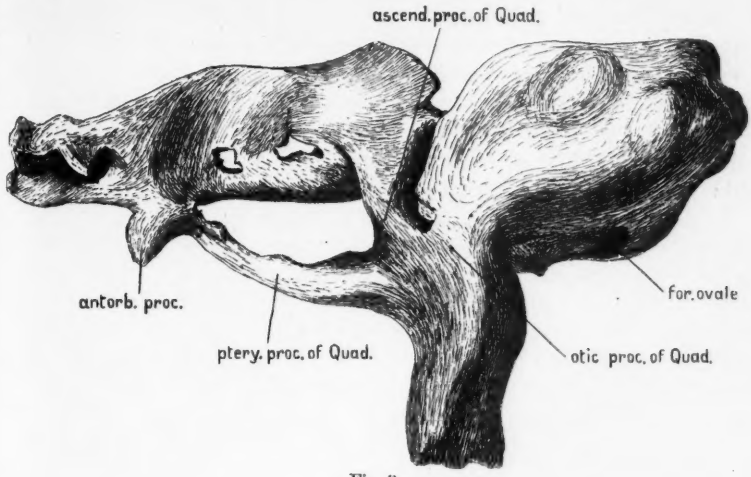


Fig. 9

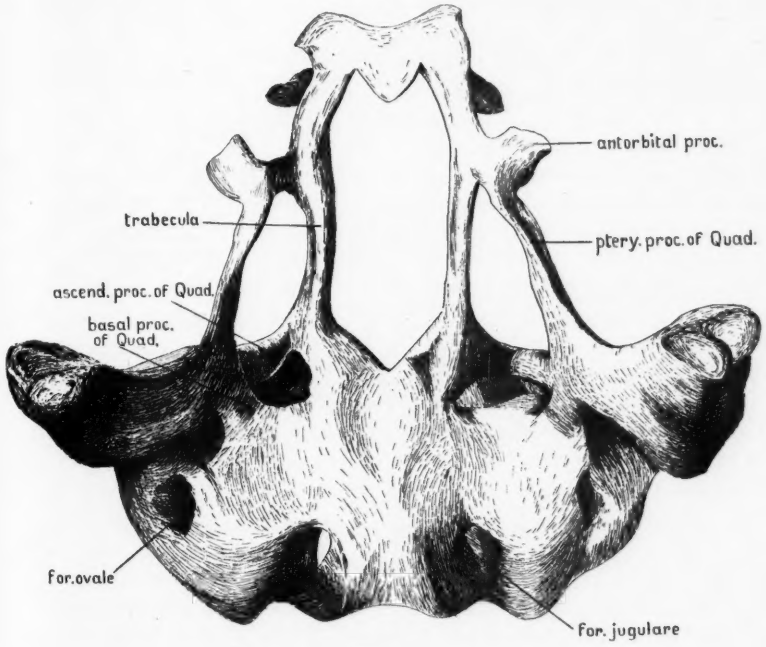


Fig. 10

Figs. 9 and 10. Hynobius larva 20 mm. Sketches of model, fig. 9 from the side; fig. 10 from below.

developed. The basal process has developed and chondrified; its inner end is confluent with the base of the auditory capsule. The columella auris is not yet developed. In a larva of 37 mm. (fig. 12) and in the adult stage, the anterior part of the pterygoid process has disappeared, and a syndesmotic joint has developed between the basal process of the quadrate and the base of the auditory capsule. The ascending and otic processes are continuous with the crista trabeculae and with the auditory capsule respectively.

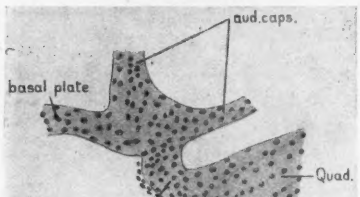


Fig. 11. Hynobius larva 20 mm. Transverse section through quadrate and its basal process.

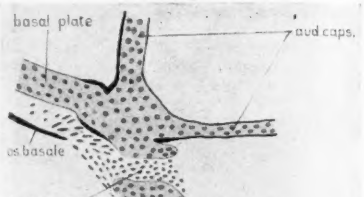


Fig. 12. Hynobius larva 37 mm. Transverse section through basipterygoid syndesmotic joint.

As regards the quadrate, there is a greater similarity between Cryptobranchus and Menopoma than between either of them and Hynobius. In the two former the ascending process passes upwards and forwards from the base of the pterygoid process, whilst in Hynobius it passes nearly vertically upwards from the body of the quadrate. In a future paper I hope to discuss the phylogenetic significance of these and of some other phenomena in Amphibia.

I have the pleasure of thanking Prof. J. P. Hill for the loan of the larva of Cryptobranchus, and Prof. Watasé for the larvae of Hynobius. Figs. 1 and 2 were drawn by Miss Cross, figs. 4, 9 and 10 by Miss Harvey.

The expenses of the investigation have been defrayed by the Bristol University Colston Society.

Sept. 14, 1922.

LITERATURE

PARKER, W. K. (1882). "On the structure and development of the skull in Urodeles." *Trans. Linn. Soc.* vol. XI.

WIEDERSHEIM, R. (1877). "Das Kopfskelet der Urodelen." *Morph. Jahrb.* Bd. III.

SOME OBSERVATIONS ON THE ROOF OF THE PRIMORDIAL HUMAN CRANIUM

By Professor FAWCETT, M.D.

It has been the custom for some time to accept the views expressed by Bolk (*Petrus Camper*, 2 Deel, pp. 315 etc.) which were based on results obtained from specimens stained in bulk by Van Wijhe's bulk stain and differentiated.

By this method results were obtained so much at variance with what obtains in vertebrates other than man, and so different from anything obtained in the usual way in man, that in 1910 I ventured to say: "I must confess the appearances in his figures scarcely explain what is seen in this cranium." Macklin in 1921 in a description of "The skull of a Human Fetus of 43 millimetres greatest length," is more precise and states that Bolk has been led into quite a number of errors through the method used. It is only fair to say that Bolk himself does not place implicit faith in the methods, for he says on p. 322, "In der mitte der occipitalregion bleibt unterhalb des Knorpelringes ein Feld übrig das nicht knorpelig verschlossen wird, *wenigstens das von mir angewendete Verfahren ist nicht in Stande einen vollkommenen knorpeligen Verschluss ans Licht zu führen.*" (The italics are mine.)

Bolk illustrated his communication by four coloured figures which represent different ages in sequence. In fig. 1 one sees from below upwards, cartilage centres in the cervical vertebrae, separate on the two sides but connected together dorsally by a spinal membrane; above the vertebrae on each side one sees cartilage in a somewhat broad sheet forming what appears to be the side of a foramen magnum, and connected together about their middle by a narrow bar of cartilage from which a small process ascends. Below this bar is an uncoloured area, Bolk's spino-occipital membrane, which is continuous with the spinal membrane below and contains two small nodules of cartilage. Above the transverse bar above mentioned is a transversely placed separate mass of cartilage.

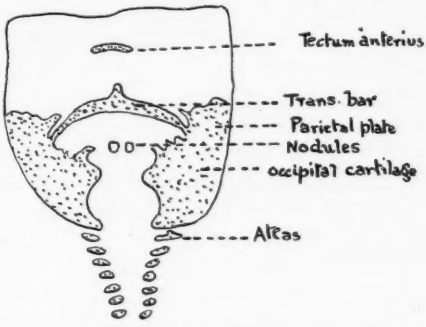


Fig. 1 (after Bolk).

Bolk regarded the spino-occipital membrane as reaching up to the transverse bar of cartilage which connects the two side walls of cartilage together,

and he rightly said that this transverse bar has nothing to do with bounding the foramen magnum. He did not actually realise that the conditions appearing in his specimen are entirely due to the method used, for all that part lying between the two small nodules and the transverse bar of cartilage is actually cartilage undergoing calcification and therefore has lost its stain during differentiation unless perchance it never was stained. Hence the upper segment of the spino-occipital membrane is non-existent.

It is hoped that this communication will show that there are in reality three tecta in the vault of the cranium, which may be named from behind forwards tectum posterius or tectum occipitale, tectum intermedium or tectum parietale posterius and tectum anterius or tectum parietale anterius.

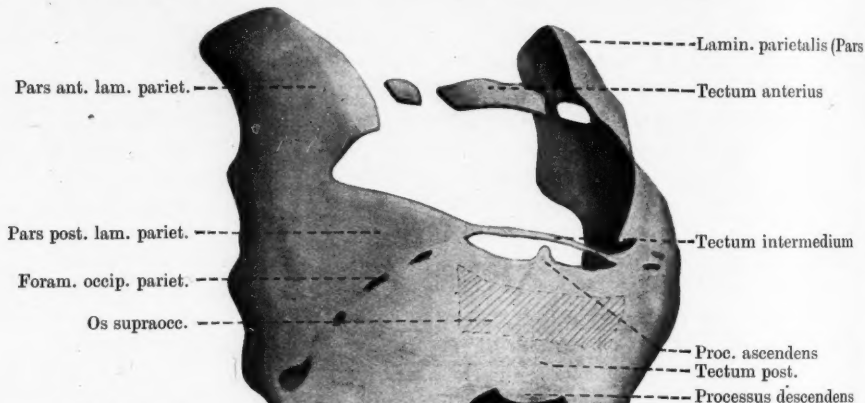


Fig. 2. A combination of appearances at about 30 mm. C.R. length. Human, viewed from behind.

Text fig. 2 shows the condition of affairs in the chondro-cranium at about the 27 millimetre crown-rump stage. The tectum posterius is seen as a broad band connecting the occipital cartilages above the foramen magnum; from its upper border in the mid-line a short ascending process projects and a broader but short process projects downwards—the processus descendens. These processes were described by me in 1910. Laterally the tectum merges into the corresponding supraoccipital, which is separated incompletely from the parietal plate by an oblique row of unchondrified areas usually associated with the auditory capsule. These areas appear as foramina in the model. They lie along the occipito-parietal groove of Macklin. If they be followed up they lead to a notch situated in the upper edge of the wall of cartilage formed by the supraoccipital cartilage and the parietal plate—Macklin has named this notch the incisura occipito-parietalis. Anterior to the supraoccipital cartilage is the parietal plate (lamina parietalis or lamina supracapsularis). This I think

should be described as consisting of an anterior and a posterior part separated by a deep notch. The posterior part is directed upwards and inwards above the outer edge of the supraoccipital cartilage. It either ends freely or is connected with the corresponding spot on the opposite side by a narrow bridge of cartilage—the tectum intermedium or parietale posterius. This tectum has only a very short life. It is not present at the 27 mm. stage and it has disappeared at the 32 mm. stage. It does not take part in the formation of the interparietal bone and it is not brought out in any of Bolk's figures.

The anterior part of the parietal plate varies somewhat in form with age but is well developed at the 30 mm. stage. As it rises in the cranial wall it broadens antero-posteriorly and posteriorly is prolonged as a short angular projection. Stretched between these posterior processes is a chain of three pieces of cartilage, viz. a median and two lateral; these constitute the tectum anterius or tectum parietale anterius.

The two lateral pieces disappear before the 48 mm. stage, but at this stage the median piece still persists. The tecta are thus:

(*a*) Tectum occipitale or posterius.

(*b*) Tectum parietale posterius or tectum intermedium.

(*c*) Tectum parietale anterius or tectum anterius.

So far as I know only the tectum posterius is converted into bone. Macklin shewed that at the stage described by him, viz. 43 mm., there was an area of calcified cartilage in the occipital tectum and the adjacent supraoccipital cartilages which assumed the form of a butterfly with outstretched wings. In my own specimens at the 27 and 32 mm. stages the same thing occurs. In fig. 2 the calcified area is shown. This area is the area which Macklin has stated is calcified and therefore has either not stained or has lost the stain during differentiation.

It is easy to see that if the stain were lost from this area two cartilaginous bars would appear to cross the mid-line from side to side and that from the upper bar a processus ascendens would project upwards and from the lower a processus descendens would project downwards into the foramen magnum. The bars would appear to be separated by a clear unstained area, which Bolk thought to be unchondrified. Further as age advances two important changes occur. The processus descendens divides into two processes (fig. 3), and both calcification and ossification so occur in and over the root of these two processes that when viewed from behind (fig. 4), the appearance given in the model at this stage, viz. 48 mm., is as if there were two separate nodules of cartilage lying in the interval between the two occipital cartilages bounding the incisura posterior of the foramen magnum. The bone which covers the supraoccipital cartilage and tectum occipitale is of a complex nature for it is partly perichondrial and partly dermal (fig. 5). If now figs. 3 and 4 be compared with one another and with fig. 1 which is after Bolk, it can easily be seen how Bolk was led into error. Fig. 3 represents the tectum posterius as viewed from the caval aspect. It will be seen that a bar of cartilage stretches from side to side

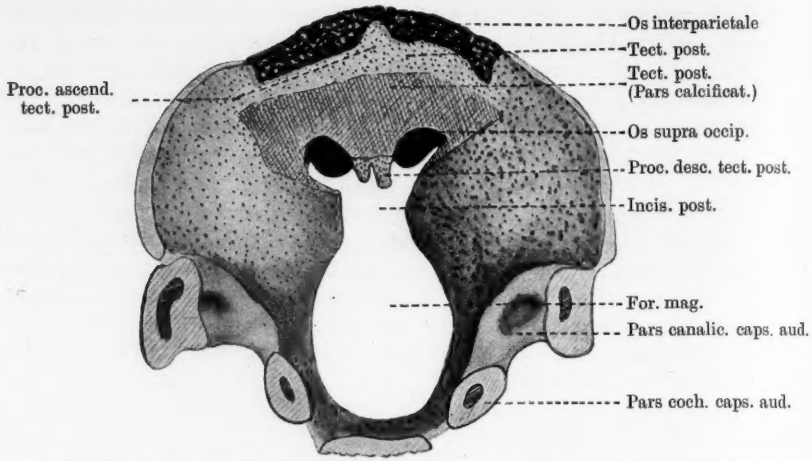


Fig. 3. Hinder part of vault of chrondrocranium of human 48 mm. C.R. embryo. Here the tectum posterius appears in its full development giving off in the upward direction the processus ascendens and in the downward direction a processus descendens which divides into two. The stippled parts represent uncalcified cartilage, the cross-hatched part is cartilage in process of calcification.

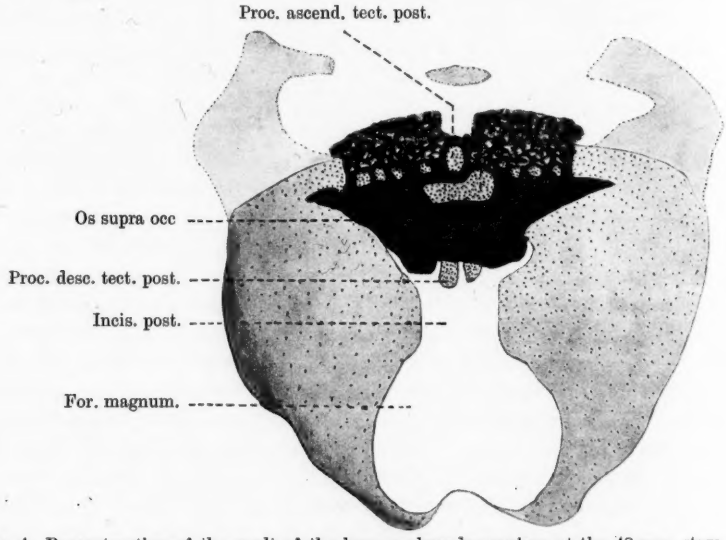


Fig. 4. Reconstruction of the vault of the human chrondrocranium at the 48 mm. stage from behind shewing how the processus descendens appears as two isolated cartilages projecting into the incisura posterior and superior of the foramen magnum.

sending upwards a single process, the processus ascendens, and a process which projects downwards and divides into two. It will be seen that a calcified area, shaped not unlike the butterfly area described by Macklin and marked on the figure by cross-hatching, so modifies the appearance of this deep bar of cartilage as to divide it into an upper bar and two lower nodules connected

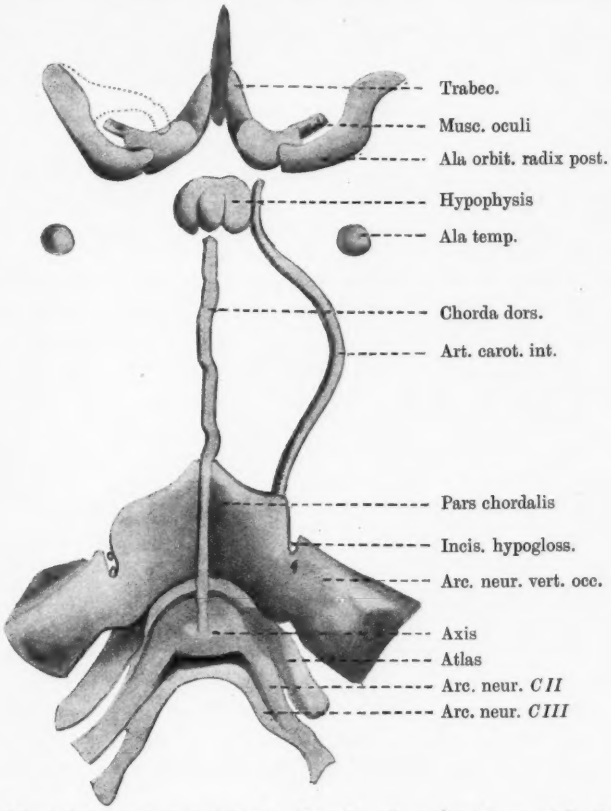


Fig. 5. Model of chondrocranium of 10 mm. *Tatusia* embryo shewing especially the trabeculæ diverging behind and giving attachment to the rectus eye muscles; the preoptic limb of the ala orbitalis is not yet laid down. The ala hypochiasmatica is the posterior free extremity of the trabecula of its side.

together above, at their bases, by a narrow band of cartilage. If the same region be now viewed from behind (fig. 4) perichondrial and mixed bone have so extended downwards over the processus descendens as to hide from view even the roots of the two processes and they appear as isolated nodules. Macklin it was who foreshadowed such an appearance, for he says, p. 66, "It is of interest, however, that this upper margin does remain uncalcified and

unossified for such a long period for, as Bolk has shown, it is present throughout his series of four human chondro-crania. In the last, however, it is becoming thinner and more attenuated. I would suggest that this cartilaginous edge may be retained to favour growth of the supraoccipital bone. A similar reason may underlie the persistence of the twin nodules of cartilage which are present in the apex of the superior occipital incisure in Bolk's preparations, and which he states agree in position in one case at least, with the bones of Kerckring. These nodules are apparently (in Macklin's model) in the same position as the processus descendens. It seems to me quite likely that they are not isolated masses of cartilage situated in membrane, but that they are connected with the calcified cartilage of the tectum above."

Fig. 5 shews the central stem of the base of the skull in *Tatusia* at the 10 mm. stage. It consists of a chordal segment and a prehypophyseal part. This latter I have usually termed for topographical reasons the pars interorbito-nasalis. In *Tatusia* this part seems to bifurcate behind and each limb then receives the pre- and post-optic limb of the ala orbitalis from above. The latter being in ontogeny the first to reach the corresponding limb of the pars interorbito-nasalis. That part of each limb of the pars interorbito-nasalis which lies on the floor of the optic foramen is the ala hypochiasmatica and from it the rectus system of eye muscles takes origin. In fig. 5 the muscular origin is shewn, only the post optic limb of the ala orbitalis has joined the pars interorbito-nasalis, but the site of the anterior limb is indicated by a dotted line. There is no lamina hypochiasmatica at this stage. This only appears at the 17 mm. stage when the two limbs of the pars interorbito-nasalis fuse together. The ala hypochiasmatica may thus be looked upon as the edge of the corresponding cornu of the pars interorbito-nasalis which lies below the optic foramen. Should the pars interorbito-nasalis be regarded as the equivalent of the trabeculae, then the alae hypochiasmaticae would be the fore ends of the posterior cornua of the same.

The figures I have submitted prove that Macklin's conjecture is correct and that Bolk's view based on a faulty method is no longer tenable.

My thanks are due to my colleague, Mr D. C. Rayner, for the embryo, and to my assistant, Miss G. R. Llewelyn, for ungrudging help in cutting out wax-plates.

REFERENCES

Bolk. *Petrus Camper*, pp. 315–27.

Macklin. Contributions to Embryology, No. 48, from Publication 273. Carnegie Institution of Washington, pp. 57–103,

Fawcett. *Journal of Anat. and Physiol.* vol. xliv, pp. 303–11.

A REPORT ON TWO CASES OF HERMAPHRODITISM IN MAN

By A. GIRGIS, M.R.C.S. (Eng.), L.R.C.P., B.Sc. (Lond.),
Lecturer in Anatomy, Egyptian Government School of Medicine, Cairo.

CASE A

The following description is of a specimen, which was removed from a body in the dissecting room of the Egyptian Government School of Medicine, Cairo, about 15 years ago. No history of the specimen is known. As regards the age, nothing can be said except it was an adult individual.

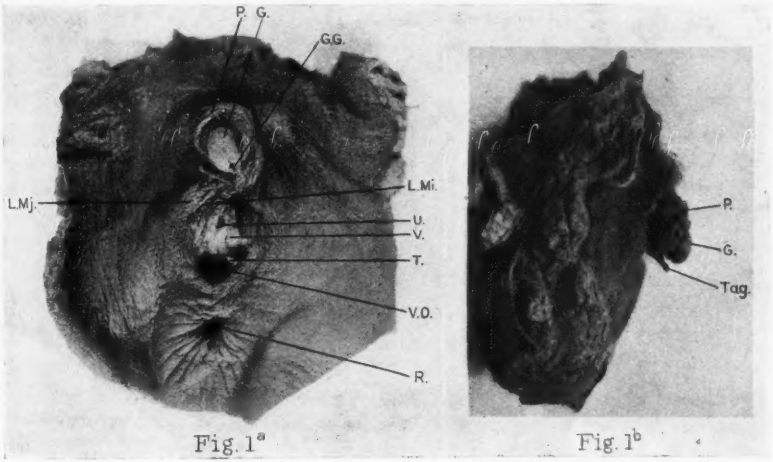


Fig. 1. Anterior and lateral views of external genital organs. *R.* anus, *G.* glans clitoris, *G.G.* genital groove, *L.Mi.* labium minor, *L.Mj.* labium majus, *P.* prepuce, *T.* tag remains of hymen, *Tag.* Tag of skin, *U.* urethral orifice, *V.* vestibule, *V.O.* vaginal orifice.

The specimen consists of female external and internal genital organs. It measures 18 cm. in length, 14 cm. in breadth and 6 cm. in thickness. It has been preserved in formalin solution, and shown in classes as an example of very enlarged clitoris.

Mons veneris—is covered with coarse thick hair, which thins out on either labium majus.

Labia majora—are shrunk but well marked, and are continuous above with a very large and loose prepuce.

Clitoris—is the most striking feature in the specimen. It is very enlarged,

measuring 33 mm. in length with a large glans 16 mm. long and 12 mm. in diameter. It is covered by a prepuce, which is relatively very extensive and can be pulled well over the glans. On its ventral surface there is a groove (*G.G.* fig. 1 *a*) extending to the tip of the glans, having the appearance of the external meatus of the male urethra. The groove is the persistent genital groove of the embryo. There are two tags of skin (*Tag.* fig. 1 *b*) one on either side of the groove at the root of the clitoris. The clitoris as a whole, apart from the large prepuce, resembles the penis of a small boy.

The external orifice of the urethra is 5 mm. in diameter and opens into a well formed vestibule.

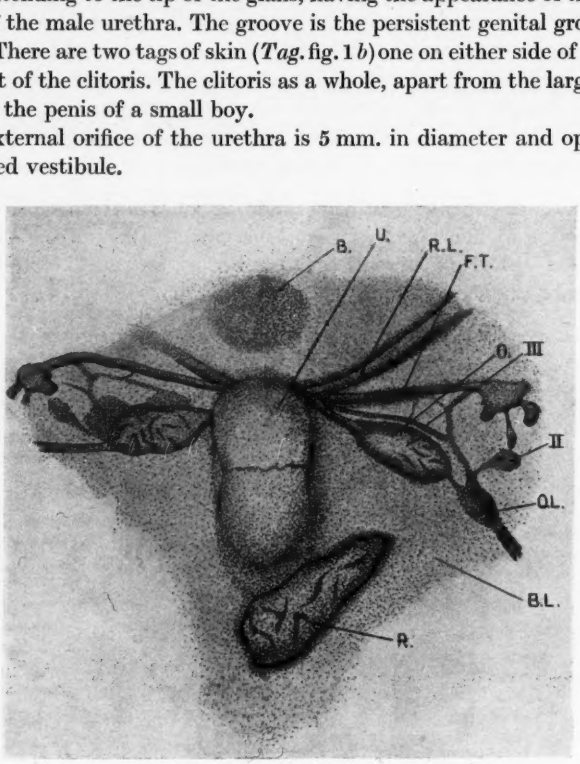


Fig. 2. Internal genital organs. Posterior view. *B.* bladder, *B.L.* broad ligament, *F.T.* Fallopian tube, *O.* ovary, *R.* rectum, *U.* uterus, *II.*, *III.* bands in broad ligament, *R.L.* round ligament.

The vaginal orifice is a large opening, about 20 mm. in diameter and its edge is surrounded by tags, the remains of the hymen. Coitus must have been practised.

Uterus—is well formed, normal in shape and size, about 70 mm. long and 34 mm. wide.

Ovaries—are well formed, normal in shape and size. Right ovary measures 35 mm. in length, 15 mm. in breadth and 6 mm. in thickness. Its lateral half is puckered, due to rupture of Graafian follicles, and indicates a functioning ovary, but its medial half is smooth. It is connected with the uterus and the pelvic wall by well formed ligaments.

The left ovary is similar to the right, but its puckering is nearly complete and it is situated nearer to the uterus than is the right.

Fallopian tubes—are normal in size, shape and position. A section of the right tube was examined microscopically with the result that it was found to be patent.

Round ligaments—are normal.

Broad ligaments—contain between their two layers bands of thickened tissue. The arrangement of these bands is shown in fig. 2. They can be felt between the thumb and index finger and are seen when the ligament is held against the light. The chief of these bands is a pyriform body (*II.* fig. 2) situated on the lateral side of the ovary. It is about 15 mm. in length, 7 mm. in breadth at its fundus, and about 3 mm. in thickness.

The structure *III.* (fig. 2) lies in a position continuous with that of the canal of Gartner. No dissection of the uterus was made to ascertain the continuity of the canal, but the vestibule was examined for the purpose of finding a possible opening of the canal. No definite opening was found, but this may have been due to the hardness and wrinkled condition of the mucous membrane.

The arrangement of the bands on the left side differs slightly from that on the right as shown in fig. 2.

Microscopical Examination

Sections were taken from the right side only at the planes shown in fig. 3.

The opposite side has been left intact to show the arrangement and continuity of the bands.

Right ovary—shows well marked cortical and medullary regions (fig. 4).

The cortex consists of compact fibrous tissue. The germinal epithelium has disappeared except that here and there a small piece is seen in a degenerated condition. This is probably due to the poor state of preservation of the specimen.

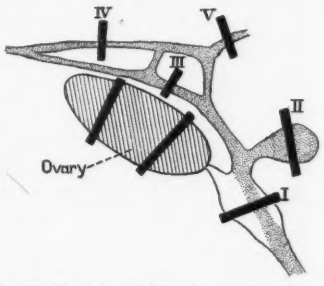


Fig. 3. Drawing of the planes of sections.

In the cortex there are structureless masses, some of which are convoluted, surrounded by a fibrous sheath (*G.F.* fig. 5).

The surface at one spot exhibits a depressed scar (*S.* fig. 5).

These masses are corpora lutea and their presence indicates the pre-existence of Graafian follicles.

The medulla is vascular and the blood-vessels have thick walls; but the striking feature of the medulla is the presence of tubules. These tubules are lined by a single layer of cubical cells with large nuclei.

The nuclei stain very badly; some of the slides were left in Delafield's haematoxylin for over 1½ hours without any appreciable effect on the nuclei resulting. The tubules have different shapes; some are circular, others oval,

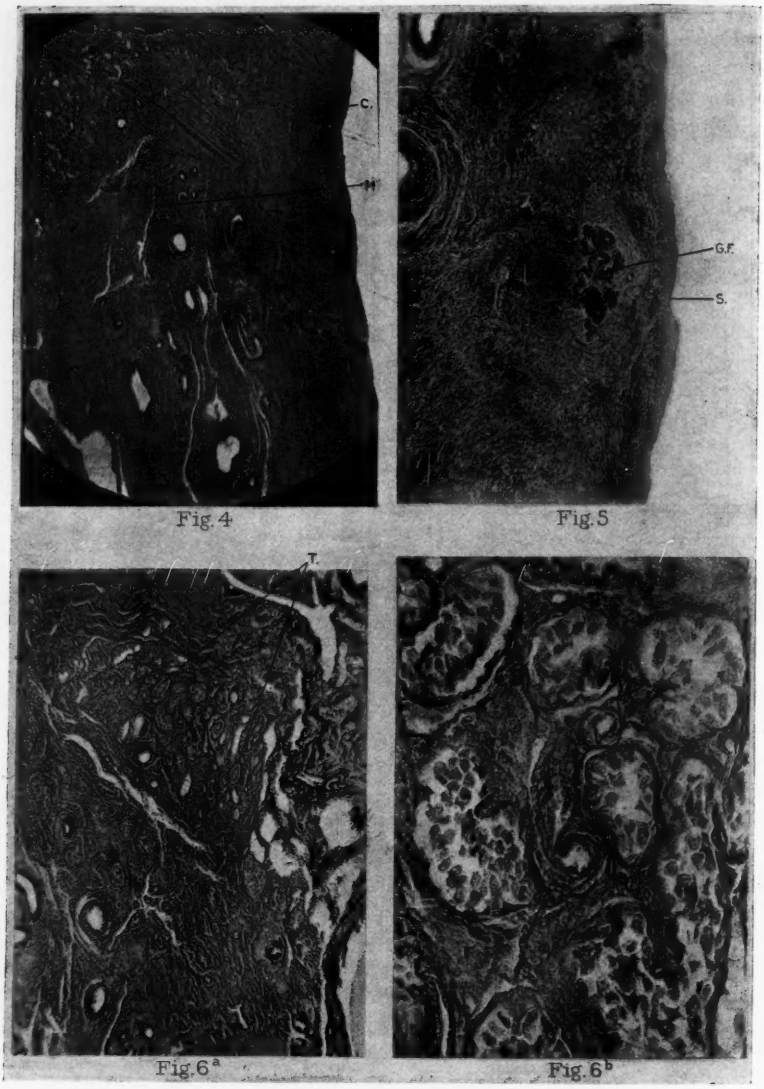


Fig. 4 Fig. 5

Fig. 6[a] Fig. 6[b]

Fig. 4. Microphotograph of right ovary showing cortex (*c.*) and medulla (*M.*).
Fig. 5. Microphotograph of the cortex showing an old ruptured Graafian follicle (*G.F.*) and a scar (*S.*) on the surface opposite to it.
Fig. 6. Microphotograph of medulla showing tubules (*T.*). *a*, low power, *b*, high power.

Fig. 7 *a*

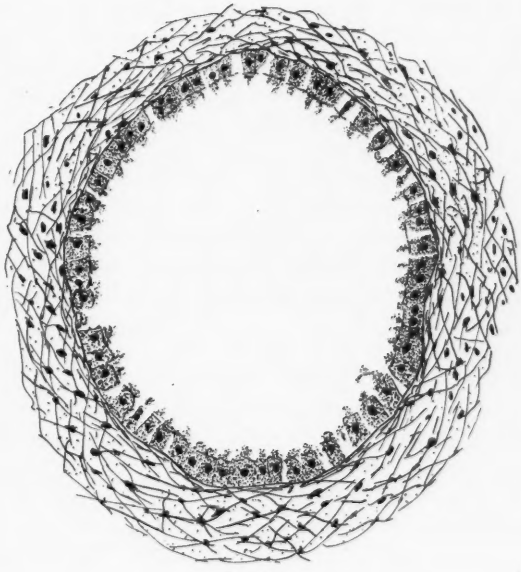


Fig. 7 *b*

Fig. 7. Microphotograph of band *II.* (fig. 3) showing the tubules (*a*) and cilia (*b*)

S-shaped or longitudinal according to the plane of section. The tubules in the upper and lower parts of the medulla are more or less circular in section while those occupying an intermediate position are longitudinal. In other words the tubules in the upper and lower parts are disposed in the long axis of the ovary, while the intermediate tubules occupy its short axis. Each tubule is surrounded by a well formed fibrous sheath, from which the cells are detached in some places owing to shrinkage. The tubules are only seen in the medial half of the ovary, which corresponds to that part the surface of which is smooth and not puckered (fig. 2).

The nature of these cells is difficult to determine as cytological examination is impossible. They undoubtedly line tubules, and the question arises, are they testicular cells in an embryonic condition or germ-epithelium cords (Pflüger's tubes) enclosed in the medulla? Pflüger's tubes are, as a rule, solid cords more likely to be found in the cortical region beneath the germinal epithelium, and in them certain large cells are conspicuous. These large cells are the primordial ova. The tubules were not found in the cortex of this ovary in any of the sections examined; but were found abundantly in the medulla. Their lining cells are more or less uniform in size. Near the cortex they lie in the long axis of the ovary, i.e. parallel to the cortex.

Bands in the Broad Ligament.

Sections were taken from the different bands in the broad ligament. The planes of these sections are shown in fig. 3. The most characteristic of these sections is the one marked *II.* in fig. 3 and is shown in fig. 7 *a* and *b*.

This shows tubular tissue surrounded by a well marked fibrous stroma. The tubules are circular, oval or S-shaped according to the plane of section. Each tubule is lined by a single layer of columnar cells. The nuclei of the cells are large, basal in position and stain badly. From the free end of the cells protoplasmic processes project into the lumen of the tubules. There appears to be more than one process for each cell, suggesting the presence of cilia. These tubules are remnants of the Wolffian body and they simulate the epididymis in man, which arises from the cephalic part of the Wolffian duct.

Other Sections.

Band *III.* in fig. 3 is shown in section fig. 8.

This shows a thick walled tubule which represents the rest of the Wolffian duct and from which the vas is formed in man.

Bands *I.*, *IV.*, *V.* (fig. 3) are shown in sections, figs. 9, 10, 11.

All the sections exhibit tubules and numerous vessels, the vessels having thick walls and large lumina. The significance of the marked vascularity and the great thickness of the vascular walls is not obvious, they may represent an embryonic condition.

CASE B

A patient was admitted to the female wards of Kasr-el-Eini Hospital, Cairo, with the object of having (her) vagina enlarged as (she) wished to get married.

Fig. 8

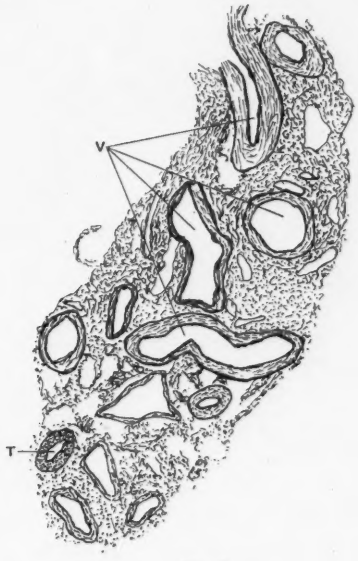


Fig. 9

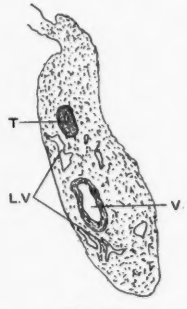


Fig. 10

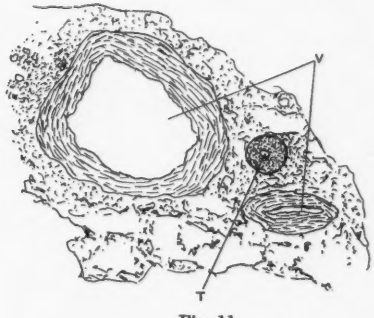


Fig. 11

Fig. 8. Microphotograph of *III.* (fig. 3) showing a tubule (*T.*) resembling the vas in man, and thick walled blood vessels.

Figs. 9, 10 and 11. Microphotographs of bands *I.*, *IV.*, *V.*, showing *T.* tubules, *V.* thick walled blood vessels, *L.V.* lymph vessels.

On examination the gynaecologist reported that the vagina was very narrow and about 3 cm. in length. It ended blindly (atresia vaginalis). No

uterus, tubes or ovaries could be felt. The following measurements were taken:

	Case B	Normal from Eden's text on Midwifery
Interspinous diameter ...	22·0 cm.	25·0 cm.
Intercristal diameter	27·5	27·5
External conjugate diameter	16·0	20·0

Age 30 years. Had been brought up and dressed as a girl. Height with bare feet 170 cm. No history of menstruation.

Two years ago (she) went to a doctor owing to "feeling peculiar in the genitals."

The doctor removed two tumours, one from either labium majus. He states in his note that the tumours were two testes with their vasa. He unfortunately threw them away without having them examined microscopically.

The voice, manners, attitude, and features were those of a man. (She) had a slight moustache but no beard. (She) stated that after the removal of the tumours (she) had had sexual desire towards men. Before the operation (she) had no sexual inclination towards either sex. (She) worked in the fields doing a man's work.

When examined in the nude state (fig. 12) the shoulders, pelvis, breast and muscular prominences were found to be typically male as were also the hands and feet. The pubic hair was shaved—an Egyptian custom.

The labia majora were well formed and showed the operation scars (*S.* Fig. 13).

The clitoris had been removed in childhood—circumcision of the girls being an Egyptian custom among the lower classes. Its root was prominent measuring 15 mm. in diameter, thus denoting a large organ.

The vaginal orifice was very narrow and there was no sign of a hymen. The urethra opened into a vestibule female in type.

The labia minora were slight but well marked.

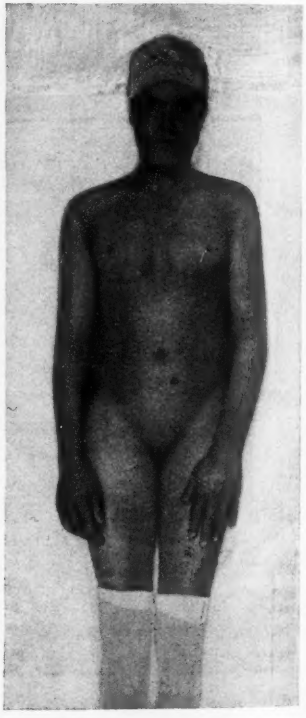


Fig. 12. Note male shoulders, breast, pelvis, hands.

There was no record of a similar condition in the family.

SUMMARY.

Case A shows the following features:

1. An enlarged clitoris with a ventral groove, an attempt to form a male penis and urethra.

2. The broad ligaments contain well developed remnants of the Wolffian bodies especially in part II. fig. 2. In this part there are tubules with ciliated columnar epithelium, simulating the male epididymis.

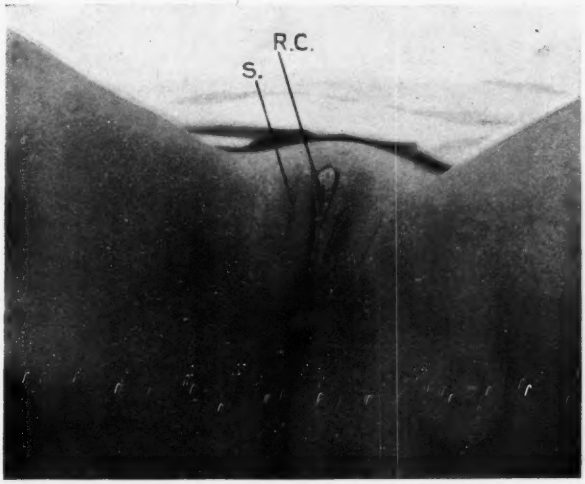


Fig. 13. External genitalia. *R.C.* root of clitoris, *S.* scar of operation.

3. The ovary shows well marked cortical and medullary regions. In the cortex there are remains of Graafian follicles. In the medulla there are tubules lined by a single layer of large cubical cells and, most probably, testicular in nature.

Case B shows the following features:

1. Male characters as far as manners, voice, absence of female breast, shoulders, pelvis and general appearance are concerned.

2. Vagina very small and ending blindly, with no sign of hymen.

3. No uterus, tubes or ovaries could be felt.

4. Presence of two tumours one in either labium majus. These tumours are believed to have been testes.

CONCLUSION

Unfortunately the two cases are incomplete. No history is known of case A and no microscopic examination was made in case B. But I venture to deduce a few points from the above observations.

In case A the external and internal genital organs are, apart from the

enlarged clitoris and the remains of the Wolffian bodies in the broad ligaments, of the normal female type. That she has had functioning ovaries is shown by the presence of Graafian follicles. There is no evidence that she has had children, but there is also no evidence against her having had any. Physiologically she is a female and morphologically she is predominantly female.

Case B represents another type. No female internal genital organs could be felt, i.e. the Mullerian ducts had, as is usually the case in the male, failed to develop. The external genital organs are at first sight of the female type, but close examination shows that the vagina, so-called, is only a small invagination and possibly represents morphologically a uro-genital sinus and is not derived from the Mullerian ducts. The absence of a hymen seems to support this view. The presence of the testes in the labia majora seems to show that the two halves of the scrotum have failed to meet in the middle line, a condition sometimes seen in hypospadias. Therefore case B is morphologically an imperfect male, but functionally (she) is a neutral individual.

What causes the clitoris in case A to enlarge and retain the genital groove thereby simulating a penis? "Embryology teaches that the mammalian embryo is potentially a hermaphrodite and the differentiation into an ovary or a testis is followed by a corresponding development of the correlated sexual organs (2)." It is further believed that the genital glands control the development of the secondary sexual organs, probably by means of internal secretion. It seems that the internal secretion does not only stimulate the development of the correlated secondary sexual organs but inhibits the development of the organs of the opposite sex. This is a point which requires confirmation by further investigations on the internal secretions. The tubules in the medulla of the ovary of case A resemble testicular tubules in an embryonic condition. If they are testicular in nature they will account for the peno-clitoris and the epididymic structure in the broad ligament. They will also support the view that "the embryonic genital gland is composite, the testicle develops within the medullary or central part of the gland, the ovary from its cortical or more superficial parts (1)."

Case A will also show that the presence of physiologically functional genital glands of one sex is not incompatible with the presence of genital tissue of the opposite sex. Cases have been reported by surgeons who have found in the hernial sacs of apparently normal individuals the genital organs of the opposite sex. Brossard (Cairo) operated on a man 26 years old in order to remove a tumour from the scrotum. This tumour proved to be a uterus measuring 9·5 cm. in length, and situated in a sac within the tunica vaginalis. The genital glands associated with it were testes which were normal and in which spermatogenesis was active. Arnolds removed from a man 59 years old, and otherwise normal, a hernial sac containing a bicornuate uterus. Keiffer removed a uterus from a hernial sac of a man, "the father of 8 children (1)." In these cases no microscopical examination of the testes was made. Bland-Sutton reported a case of a boy "who has male external genital organs with un-

descended testicles." The penis was normal in shape and size. The scrotum was apparently normal but empty of contents. Situated above the prostate was a uterus of the size and shape corresponding to that of a girl of the same age. The genital glands occupied their proper relation to the Fallopian tubes but presented the smooth ovoid contour of a testis. On microscopical examination the glands were found to be testes." It is not stated whether the whole glands were examined microscopically or only a part.

What caused the failure of the external genital organs in case B to develop into normal male organs? Was it due to imperfect testes (pseudo-hermaphrodite) or was it due to the presence of ovarian tissue either in the testes or in the abdomen, a true hermaphrodite? It is not possible to answer this question definitely as the testes were thrown away and the abdomen was not opened. However Gudernatsch reported a case very similar to case B. His case was that of an individual brought up as a female. The external genital organs were of the female type but the clitoris was extremely enlarged. The vagina ended blindly and no uterus was present. The mammary glands were not developed. A tumour was removed from the right inguinal region. The tumour proved to be a testis. In the testis was imbedded a nodule 3 mm. in length 2 mm. in width and thickness which proved to consist of ovarian tissue. The smallness of the ovarian nodule shows how easily it can be missed should only a part of the testis be microscopically examined.

My thanks are due to Professor Derry for his great encouragement and very valuable suggestions and criticism, to Dr Amin Bey for putting the specimen of case A at my disposal, to many other members of the staff of Kasr-el-Eini for their help in many ways and to Mr F. W. King, assistant in the Physiological Laboratory, for helping me in taking the microphotographs.

REFERENCES

(1) Arthur Keith. *Human Embryology and Morphology*, 1921.
(2) Bland-Sutton. *Lectures and Essays*, 1920.
(3) Gudernatsch. "Hermaphroditism verus in man." *Amer. Journ. of Anat.* (1911), xi.

MALFORMED HEART WITH REDUNDANT AND DISPLACED TRICUSPID SEGMENTS AND ABNORMAL LOCAL ATTENUATION OF THE RIGHT VENTRICULAR WALL

By ALEXANDER BLACKHALL-MORISON, M.D., F.R.C.P.

In 1920 there were published by Dr Shaw and myself in the *Journal of Anatomy* (Vol. LIV, p. 163) particulars of a case under my care in the Great Northern (now Royal Northern) Hospital which showed combined cardiac and genito-urinary anomalies. The cardiac condition consisted in a redundancy of the anterior, low insertion of the posterior, and rudimentary state of the septal cusp of the tricuspid valve. The right ventricle was dilated and hypertrophied, the auriculo-ventricular orifice wider than usual and the clinical signs indicative of the condition were a tricuspid regurgitant bruit and strikingly marked accentuation of the first sound of the heart. The patient died of tuberculous meningitis.

On the 27th of February, 1922, there was brought into the Royal Northern Hospital the dead body of a man, 33 years of age, on whom an inquest was held and in the course of post-mortem examination, Dr Shaw, the Pathologist to the hospital, found a cardiac state which reminded him of the case to which I have already referred, and which we reported together to the Anatomical Society. He saved the heart for my inspection and examination in detail, and has given me permission to exhibit it to the Society on this occasion.

No particulars of previous illness transpired at the inquest and discovering the address of the widow later, I learned from her, to whom I addressed a series of questions, the following particulars which may be given in her own words: "He made no complaint of any kind during the years I knew him. His occupation was that of an electrical condenser maker. No doctor has attended him for the past twelve years. He appeared to be a fully healthy man and only appeared to be extremely tired at times. He appears to have had no knowledge of any defect until rejected when a candidate for the police at the age of twenty-one years." I was also informed from another source that he had been rejected when examined for military service during the war, on account of a cardiac defect which was detected. He therefore evidently gave some physical signs of his condition although not subjectively suffering.

The pathologist's notes of the necropsy are as follows: "*Summary.* Congenital malformation of tricuspid valve. Body of a well-nourished man. No evidence of external injury or violence. Hypostasis present posteriorly. *Head.* No wounds on scalp. Membranes natural, brain 51 ozs. natural. Skull vault and base natural. *Chest.* Pleura; old adhesions between parietal and visceral

layers. Lungs: right, 21 ounces, left, 17 ounces. Both (with) passive hyperaemia.

Heart and Pericardium. Weight 15 ounces. Right side much dilated and wall of ventricle very thin. Tricuspid orifice admits (the) whole hand easily. Segments attached very irregularly to wall of ventricle. Septal cusp small and vertical; posterior cusp attached low down; right cusp reaches about to apex. Large area of wall of ventricle situated above the attachments of the segments. Other valves natural. Pericardium natural.

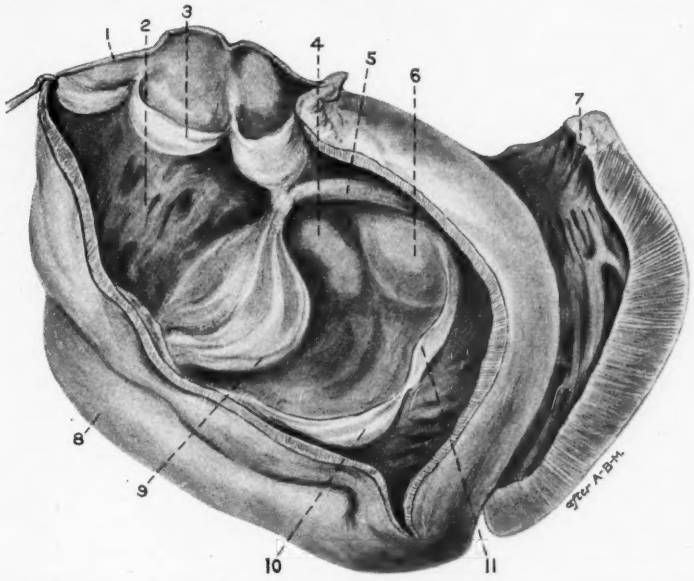


Fig. 1. Malformed heart with attenuated area in right ventricle and low insertion of tricuspid segments, the anterior cusp being redundant. 1, pulmonary artery; 2, conus arteriosus; 3, pulmonary semi-lunar valves; 4, large pars membranacea septi illuminated from the left ventricle; 5, papillary band; 6, internal cusp of tricuspid valve; 7, left ventricle; 8, right ventricle; 9, anterior cusp of tricuspid valve; 10, 11, posterior cusp of tricuspid valve.

Stomach. Evidence of recent meal. Passive congestion of mucous membrane. Intestines natural.

Kidneys. Weight together 11½ ounces. Firm. Capsule strips easily. Size natural. Passive hyperaemia. *Liver.* Weight 61 ounces. Passive hyperaemia. *Spleen.* Weight 5 ounces. Size natural. Firm. Slight congestion."

The following are the more exact measurements which I made and the details of the heart in question.

Pulmonary arterial circumference, 8 cm.; valves normal. Tricuspid valvular orifice (for it is not the atrio-ventricular orifice), 7·5 cm. by 7·5 cm.; anterior cusp 4·5 cm. deep, 6 cm. long; posterior cusp 2 cm. in depth at deepest, 5 cm. long; internal cusp 2 cm. deep, 3 cm. long.

Pars membranacea septi 2 cm. by 2·5 cm. Right ventricle 10·5 cm. by 8·5 cm.; ventricular wall 4 to 5 mm. at thickest.

Base of the anterior segment of the tricuspid valve attached at the auriculo-ventricular junction and the segment itself to either side of a large *flattened* papillary muscle from the lower end of which a second papillary muscle gives attachment to the outer end of the posterior segment; the *base* of which is

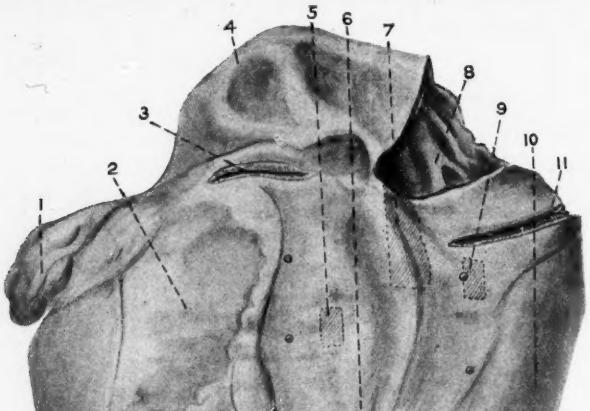


Fig. 2. Malformed heart with attenuated area in right ventricte and low insertion of tricuspid segments, the anterior cusp being redundant. 1, left auricular appendix; 2, left ventricle; 3, coronary sinus laid open; 4, right auricle; 5, 7, 9, portions removed for microscopic examination; 5, in attenuated area of right ventricle; 7, in auriculo-ventricular boundary of attenuated area; 9, in right border of attenuated area; 6, one of a series of pin-heads showing the extent of the attenuated area; 8, muculi pectinati at the entrance to the right-auricular appendix; 10, the left ventricle; 11, the right coronary artery laid bare. B.O. male æt. 33 years.

3·5 cm. from the ventricular apex and 5 cm. below the auriculo-ventricular line. A very much attenuated portion of the posterior ventricular wall in the shape of an inverted triangle, measures 4·5 cm. by 5 cm.

The right auricle measures 7·5 cm. by 5 cm. Its wall is thickest, 1 cm., at the anterior part of the circumference of the superior vena cava and over the rest of the cavity is from 2 to 3 mm. thick. The foramen ovale is closed and large, measuring 2·5 cm. by 2·5 cm.

The coronary sinus is normal in position and has a short Thebesian valve. The inferior vena cava is normal and shows a Eustachian valve. The auricular appendix is likewise normal and the musculi pectinati well-marked.

The left ventricle measures 8 cm. by 7·5 cm., the average thickness of its walls being 1·5 cm. The aortic and mitral valves are normal. The right coronary arterial orifice is large, the left small. There is some atheroma in the sinuses of Valsalva. The aortic circumference is 6 cm.

The left auricle measures 10 cm. by 4·5 cm. Its walls average 2 to 3 mm. in thickness. Microscopic sections of the attenuated area, at the level of the coronary vessels (sulcus), and far above the insertion of the posterior segment of the tricuspid valve show the auricular to be quite distinct from the ventricular musculature and demonstrate the area in question to be purely ventricular. Sections from the most attenuated part of this area show a sheet of muscle, while its lateral junction with the thicker ventricular wall is in normal muscular continuity. Any muscular action of this area would follow auricular systole, but tend to open, not to close, the tricuspid valve.

The subvalvular portion of the ventricular cavity is thus limited abnormally, and, notwithstanding the capaciousness of the anterior segment of the tricuspid valve there must have been free regurgitation and all round blood pressure in the chamber which accounts for the abnormal size of the valvular orifice and the general thinness and flattening of structures in it. The weight of the heart being fifteen ounces, that is, rather over the average weight of the normal male heart, shows that some attempt at compensatory hypertrophy had been made to deal with the circulatory difficulty. A noteworthy fact is the relative position of the internal cusp of the tricuspid as regards the pars membranacea septi and as regards the papillary band, which is the left attachment of the anterior segment; the pars membranacea being posterior to and not covered by the internal or septal segment, a fact which may have developmental significance. Like the membrane closing the foramen ovale, the pars membranacea is abnormally large, but both the auricular and ventricular septa are complete, while the chief papillary muscle is quite flattened. The coronary sinus is normal in position, and the auriculo-ventricular bundle of His may be, but the latter point has not been determined positively. Sections of a large branch of the right coronary artery in the right auricle show considerable thickening of the intima and some flattening of the lumen, but there is no general increase of intima in the arteries, taking the membrane of Henle as a guide. There is neither naked-eye nor microscopic evidence of muscular deformation and sections of a papillary muscle from the left ventricle show no interstitial increase, but sections from the attenuated area in the right ventricle reveal a loose spreading intercellular connective tissue. The attenuated area is not degenerative and pathological, but developmentally deficient.

The break in the continuity of the fibrous ring at the auriculo-ventricular boundary of the area of attenuated ventricular wall which allowed distension, together with the low position and ineffective closure of the valve segments

resulting in the dilated dextral chambers, is a striking testimony to the importance of the fibrous support of the valvular apparatus and of the valves themselves, in the cardiac mechanism of the circulation. It was the fashion not long ago to decry the importance of the integrity of this factor. One rarely meets with such eloquent evidence to the contrary as is afforded by this case and the importance of this factor is not less but greater in the left or systemic arterial heart.

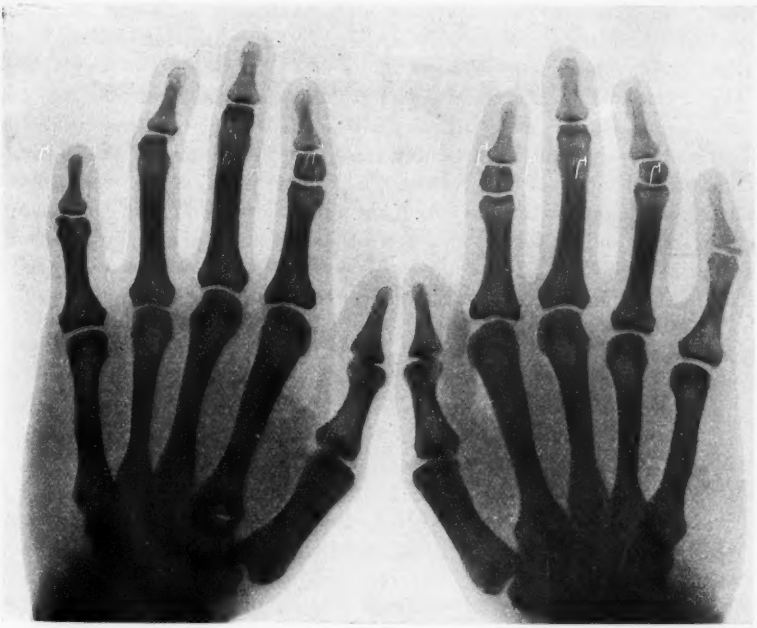
In the unfortunate absence of a record of the clinical signs in the case of B.O. some of the clinical physiology must be left obscure, but much may be deduced from the anatomical details given. His sudden death without a history of previous ill-health is interesting, as in many other cases of heart disease so dying. I shall not, however, comment further on this fact, beyond stating my belief that, if in the case of B.O., the foramen ovale had remained patent, it is probable that he would have lived longer. In support of this opinion, I may recall to the memory of members of this Society the case of an old man of whom I gave an account in 1917 (Vol. LII, p. 251), and who, with an almost obliterated pulmonary artery and very hypoplastic or rudimentary right ventricle, lived to a venerable age, because he had, like B.O., a sound left heart, but also a widely patent foramen ovale, which gave easy access of the right heart blood into the left chambers.

FAMILIAL ABNORMALITIES OF THE MIDDLE PHALANGES OF EACH HAND

By R. C. D'ARCY HANN, B.A. (Cantab.)

The condition about to be described seems extremely rare, a search of what literature is available revealing no parallel case.

It is to be regretted that a more detailed account cannot be given owing to difficulties made by the patient: for example, an examination of the feet was refused and of the family history it was only certain that of seven or eight members similarly deformed the mother, her brother, and sister were included. The man examined had no brothers and only one sister and she was unaffected.



The mother and son were seen and the condition on examination seemed exactly similar. The radiograph and description is that of the son aged 19. The hands were not greatly ill-shaped though they had an appearance of squatness; the first impression on inspection being that all the first interphalangeal joints were missing. The movement at the terminal joint was very

free and so comparatively little disability of the hand resulted. On examination of the radiograph the striking feature is the restriction of the abnormality to the second phalanges, all of which are involved.

The deformity is symmetrical but for the fact that in the ring finger of the left hand the segment representing the second phalanx has become united to the proximal phalanx. The bone representing the second phalanx varies from a small fragment in each little finger (strangely displaced laterally) to well formed segments, with normal joints above and below in the ring and index fingers, whilst in the middle finger and right ring finger the segments have actually fused. The line of union is obvious and there has been no suggestion of a joint.

We may also note a tendency to a displacement of the terminal phalanges towards the middle line of the hand.

There seems no doubt that the proximal and terminal phalanges are normal and the interpolated bones are not abnormal epiphyses.

An interesting comparable case was published by Dr Drinkwater (in this journal)[1] of a family showing abnormal segmentation of the index and middle fingers. The fault there was entirely confined to fingers whereas here only one phalanx is concerned.

Under the belief that a hand deformity existed throughout many generations of an old family of the British Peerage the writer, in answer to a letter he had sent, received an account from a well-known member of the family.

She writes: "Some of my great uncles had deformed joints in their fingers, the first joint being absent, and two of them had only one joint in each thumb. My own aunts and uncles all had perfect joints, but I personally have only one joint in each thumb."

The writer is indebted to Dr Scargill for the excellent radiograph.

[1] *Journ. Anat. and Phys.* vol. L. 1916.

A CASE OF ARRESTED DEVELOPMENT OF THE THYROID GLAND ASSOCIATED WITH DWARFISM AND GREAT OBESITY

By CECIL McL. WEST, M.C., M.B.
University Anatomist, Trinity College, Dublin

The unusual condition in the thyroid gland, and other anatomical peculiarities in the present case make it, I think, worth recording.

The case was that of a female subject well advanced in years (the exact age is not known), which came into the Anatomical Department of Trinity College, Dublin, some months ago. The subject was an obvious dwarf, being only 4 feet 4 inches in height. The subject suffered from marked obesity, there being four inches of fat in the lumbar region just above the iliac crest, and in other regions the fatty layer was correspondingly thick.

The skin was thrown into numerous folds round the limbs; the face was large and fat, the nose was squat and splayed out on the face, the root being much retracted. The lips were thick and coarse, the whole face had a distinctly myxoedematous appearance. Hair was plentiful on the head and there was a considerable growth on the upper lip.

The limbs were short and fat, and the hands had somewhat the appearance of the "main en trident."

The muscles were well developed with short thick bellies. Especially well developed were the subcutaneous muscles, such as the occipito-frontalis.

There was considerable increase in the fibrous tissue, which was very noticeable at the points of attachment of the muscles to bone, as for instance was the case in the trapezius and in the pectoralis major.

The capsules of the shoulder and hip joints were much stronger and thicker than usual.

The vessels were somewhat larger and more tortuous than usual. The common carotid artery divided at the level of the hyoid bone. The heart was very fatty, but otherwise appeared normal.

The nerves were larger and thicker than usual, and some of the larger nerves, such as the sciatic and the branches of the brachial plexus ran a tortuous course, suggesting that they were too long in comparison with the neighbouring structures.

The base of the skull was considerably reduced in the antero-posterior diameter, the length from basion to nasion being 84 mm., as against 95 mm. which I found to be the average length in 27 normal skulls. This explains the retraction of the root of the nose, already noted, and in this respect the

condition of the skull is like that seen in achondroplasia, but there the resemblance ends. The characteristic flattening of the base of the skull and the great expansion of the cranial vault so often seen in achondroplasia were absent. The bones of the skull were rather thicker than usual.

The long bones of both extremities were very short; the arrest in development affecting the shafts rather than the epiphyses, which seemed too long for the shafts.

Muscular markings were very well shown; this feature may have been associated with the increased quantity of fibrous tissue, already noticed in the muscular insertions.

Fig. 1. Camera lucida drawing of face and neck from left side. *A*. Thyroid gland. *B*. Parotid gland. *C*. Sublingual gland. *D*. Submaxillary gland. *E*. Anterior belly of digastric.

In both the shoulder and hip joints there was evidence of arthritis deformans; the head of the femur was much flattened and a new pressure articular facet had been formed on the summit of the great trochanter. The tibia and fibula were of almost the same length, and the greater length of the fibula over the tibia often seen in achondroplasia was not observable. The relative lengths of the long bones to each other was normal, the upper and lower limbs being affected to an equal degree. The pelvis was narrowed, especially in the antero-posterior diameter, the conjugate measuring 84 mm. and the transverse diameter 122 mm.

On opening the abdomen the great omentum and mesentery were found to be loaded with fat; the liver presented a curious appearance seeming at first sight to be transposed, but this was found not really to be the case, but the

left lobe was like the normal right lobe in appearance and the right lobe was like the normal left lobe; the relationship of the various neighbouring structures was as is seen in the normal subject, the inferior vena cava being placed to the right of the Spigelian lobe, and the stomach occupying a concavity on the inferior surface of the large left lobe.

The internal genitalia appeared well developed and were very easily seen owing to the contracted state of the pelvis.

There was no evidence of the thyroid gland in its usual position but in the middle line just under the mandible, a tumour was found, having the shape and size of a golf ball. This was not noticed at first owing to the great accumulation of fat in the neck region.

The tumour was slightly moveable in the vertical and horizontal planes, and was fixed to the anterior surface of the hyoid bone by a short pedicle. On examination this tumour was found to be the thyroid gland.

The gland had on its superficial surface a rich venous plexus, and was covered with a thin film of muscular fibres derived from the anterior bellies of the two digastric muscles which were spread out over it.

The mylohyoid muscles did not meet in the middle line but were separated from one another by the thyroid gland, and in addition the left sublingual gland, which was apparently much enlarged had sunk down in front of the anterior border of the left mylohyoid muscle and was lying in the digastric triangle. The geniohyoid muscles of each side were spread out over the thyroid gland, the right muscle passing down to the hyoid bone and the left one being inserted into a capsule which enclosed the gland. As has been mentioned the gland was attached to the anterior surface of the hyoid bone by a short pedicle. The dissection was carried laterally to determine the blood supply of the gland, and it was then found that all the salivary glands appeared to be much increased in size. On microscopical examination it was found that the apparent increase in size was due to the great accumulation of fat among the lobules of the glands and not to any actual increase in the size or number of the glandular cells.

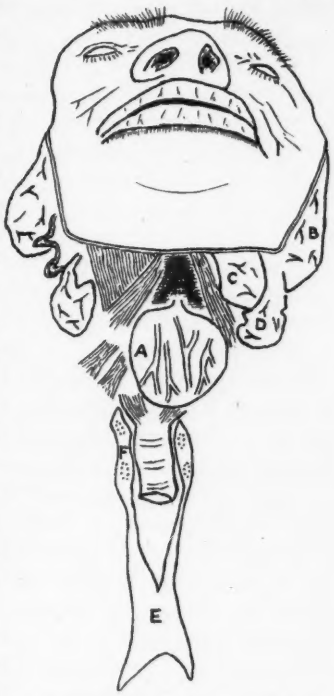


Fig. 2. Semidiagramatic camera lucida drawing of face and neck from in front. *A*. Thyroid gland. *B*. Parotid gland. *C*. Sublingual gland. *D*. Submaxillary gland. *E*. Mass of fat extending into the thorax and containing thymus tissue. *F*. Mass of fat lying on each side of the trachea and having embedded in it parathyroids (shown by dotted lines).

The thyroid gland received its blood supply almost entirely from the left lingual artery which divided into two branches, one for each side of the gland. The superior thyroid artery also sent a small branch to the gland, but this artery was not nearly as large as usual, its largest branch being that to the sterno-mastoid muscle.

The rich venous plexus which covered the thyroid gland was connected above with a number of veins coming down from the floor of the mouth, and on each side with a number of large veins which ran with the hypoglossal nerve on the hyoglossus muscle. The plexus on the thyroid gland was drained by a large vein which joined the internal jugular.

The tongue was examined but there was no evidence of a foramen caecum or of a thyro-lingual duct.

A portion of the thyroid gland was removed for microscopical examination. On section the superficial part was tough and fibrous, and in the deepest part were quite definite vesicles filled with a colloid-looking material.

The gland was seen to be enclosed in a fibrous capsule; in the superficial part were very small vesicles with hardly any lumen and containing no colloid, and having large numbers of blood vessels lying in close relationship to them. The great vascularity was one of the most striking features of the section. More deeply there was a complete absence of vesicles, and only degenerating fibrous tissue containing small calcareous masses could be seen. More deeply still this fibrous tissue gave place to large distended vesicles filled with colloid. In some places the cells forming the walls of these vesicles appeared flattened out, whereas in others they had undergone proliferation and projected into the cavities of the vesicles, some of the cells here and there appeared to be lying free in the vesicles.

Doctor A. C. O'Sullivan kindly examined the sections for me and believed they resembled those from cases of parenchymatous goitre.

In the position usually occupied by the lateral lobes of the thyroid gland, were two masses of fat lying one on each side of the trachea and passing backwards under the common carotid artery to the sides of the oesophagus.

On turning these fatty masses forwards, two small dark nodules were found embedded in their posterior aspects on each side, one about half-an-inch above the other. On section these proved to be parathyroids. The masses of fat on each side received a blood supply from the inferior thyroid artery which was much smaller than usual. Two veins of quite large size passed from each of these fatty masses, one upwards to the internal jugular vein, the other downwards to the left innominate vein.

The masses of fat were continuous below with a large median mass which extended down into the thorax in front of the great vessels; on section this mass of fat was found to contain thymic tissue.

Portions of the salivary glands were examined microscopically. They contained large quantities of fat which, separating the individual lobules, accounted for the apparent great increase in size of the glands.

The pituitary did not appear to be enlarged. Sections showed a good deal of colloid material in the anterior lobe, great vascularity and the presence of an equal number of eosinophil and basophil cells. The pars intermedia was not at all definite but there was a large quantity of colloid between the anterior and posterior lobes. The posterior lobe appeared normal. The suprarenals did not show any unusual features.

It is now generally recognised, I believe, that the thyroid gland is developed from a single median rudiment which grows down from just behind the tuberculum impar, and that there are no lateral pharyngeal diverticula taking part in its formation. This view is supported by the condition present in the case described. There was no evidence of thyroid tissue in the position usually occupied by the lateral lobes.

That the thyroid mass was attached to the anterior surface of the hyoid bone is what one would expect to find, remembering its mode of development. The parathyroid glands were normally developed.

The mass of fat which occupied the normal position of the thyroid gland coming into close relationship with the parathyroids on each side and being continuous with the median mass in front of the great vessels at the root of the neck and upper part of the thorax is of interest, as it filled very accurately the position occupied by the embryonic thymus gland. As has been noted microscopical sections proved the existence of thymus tissue in this mass.

As concerns the conditions found in other parts of the subject, it was at first thought the case resembled achondroplasia, and in some respects it certainly recalls the condition. The appearance of the face, the retracted nose, the shortness of the base of the skull all bear some resemblance to achondroplasia. The pelvis, although narrow, is however by no means so small as in typical cases of achondroplasia. On the whole, I believe the case most closely resembles myxoedema. There is evidence of deficient functioning of the thyroid gland with an apparent attempt at compensatory hypertrophy in the deeper parts of the organ, and many of the features of the case recall the picture described by R. McCarrison[1] in his book on the thyroid gland, under the heading of myxoedema.

In conclusion I should like to thank Prof. A. Francis Dixon for the help I have received from him.

[1] R. McCarrison, *The Thyroid Gland*, London, 1917.

AGE CHANGES IN THE PUBIC SYMPHYSIS. VII. THE ANTHROPOID STRAIN IN HUMAN PUBIC SYMPHYSES OF THE THIRD DECADE

By T. WINGATE TODD, M.B., F.R.C.S.

Director of the Hamann Museum and Henry Wilson Payne Professor of Anatomy Western Reserve University, Cleveland, Ohio.

CONTENTS

	PAGE
Introduction	274
Mammalian features of the symphysis pubis	277
Peculiarities of the human symphysis	278
An anthropoid strain in the Negro symphysis	280
Effect of the anthropoid strain upon phase sequence in the Negro	283
The regressive type of Negro symphysis	285
Negro symphyses of intermediate type	287
Phase and age relationships of our Negro male symphyses of the third decade	287
Groupings in the male White symphyses	289
Relative frequency of the types in Whites and Negroes	291
Relation of the types to acceleration and retardation of phase	291
Relative importance of the several symphysial features as age indicators	293
Summary	294

Introduction

The Hamann Museum of Comparative Anthropology and Anatomy of Western Reserve University is unique of its kind. Recognised two years ago by formal vote of the trustees, this integral part of the Anatomical Department grew out of the personal collections of Dr Hamann himself as Professor of Anatomy, collections which were intended to illustrate upon the Hunterian principle the life-history of Man and other animals and the diseases to which Man is subject. For years past the trustees have annually subscribed funds to extend and to care for the collections which Dr Hamann originally made and which he has continued so generously to increase. Other gentlemen, notably Dr Weber, Mr Newton T. Baker and Mr G. G. Marshall have associated themselves with this effort and now the Museum is the central feature of the department around and in which the teaching and research of the laboratory are carried on. The unique character of the institution lies not in its size or in its scope, considerable as these are, but in the opportunities which it affords for anatomical work of the most exact type. Dr Hamann had a very large share in formulating the Anatomical Laws of the State and built up a public confidence in the Anatomical Department whereby Municipality and Medical School could share

a common responsibility. This rendered possible the large and growing collection of human skeletons, now numbering 900, with accurate data obtained during the life of the individual. Dr Hamann saw the impossibility of carrying on efficient work without a comprehensive library housed in the Museum itself and provided that most valuable instrument in the first instance, thus saving the staff loss of time which would otherwise have been entailed through having to refer to a general university or centralised library for journal files and monographs while actively engaged in research. Technical help was provided on the same generous scale as the equipment, and the trustees, entering sympathetically into the realisation of this vision, have built up a laboratory which is an inspiration to those who have the privilege of working therein.

On former occasions I have discussed the possibilities for the advancement of anatomy afforded by this organisation and therefore I will content myself now with the simple statement that the object of the researches at present under way is the study of the life-history of Man's body as exemplified by the races on the North American continent, notably of White and Negro stock.

It is with this in mind that during the past ten years we have been examining skeletons of known age, seeking to elucidate the changes in feature, texture and composition of the bones following age, sex and race. Much has been done but relatively little published owing to the necessity of gathering enough data and material to give our statements the authority of proof rather than the suspicion of assertion. It is not the spade work that one has now to consider so much as the presentation of facts. For the investigations have disclosed numbers of untouched problems which can be solved only upon just such a material as we now have here.

In making a survey of the pelvis some three years ago I found that the symphysial area could yield much information which, though actually of a phyletic nature, might nevertheless be used to help in that most fascinating and elusive of determinations, namely the approximate age or relative position in the life span of an individual of adult and not yet senile years. Just as there is a definite march of the individual through the successive life periods from birth, in growth of youth and metamorphosis of adult life to senility and ultimately to death, so we may recognise the progress in similar stages of various of his tissues. For some of these, the hair and skin and arteries, we realise already the successive phases but in this respect the skeleton has hitherto seemed a document in so strange a language that merely a scattered paragraph or a page at random has been deciphered. Even facts known to occasional writers of the past have sunk into oblivion because they have never found their way into textbooks and but rarely into the current literature of the day.

One finds, however, that, like the other tissues, the skeleton has its age features. They are of a nature peculiar to the tissue of which the skeleton is composed. They do not disclose themselves to the worker in miscellaneous grave-yard material but may be readily ascertained from a large collection of material of known origin, with accurate data, and prepared by a uniform and

standardised method. It has also been possible to show that the changes undergone by bones are not limited to the human skeleton but may be discovered with equal readiness in the skeletons of other animals and, relatively to the life span at least in the case of mammals, at approximately the same periods.

In previous works I have sketched the derivation of the symphysial area from its condition in the Reptilia, its life-history in the Mammalia, its general Eutherian characters and its various phases in Man. For a full discussion of these problems the reader is referred to the following writings:

I. "The male White pubis." *Journ. Phys. Anthropol.* 1920, III. 285–334.
II. "The pubis of the male Negro-White hybrid." *Ibid.* 1921. IV. 1–25.
III. "The pubis of the female White series." *Ibid.* 1921. IV. 26–39.
IV. "The pubis of the female Negro-White hybrid and assembled results for Man." *Ibid.* 1921. IV. 40–70.
V. "Mammalian pubic metamorphosis." *Ibid.* IV. 333–406.
VI. "The interpretation of variations in the symphysial area." *Ibid.* IV. 407–424.

It is one thing to discuss in the light of a large amount of material the general changes undergone by a particular area during the total life period; it is quite another matter to take up a single case and attempt to read from it the indications of age when one has never had the opportunity of consulting the entire material upon which the general statements have been based. This latter procedure is especially difficult in the case of Man whose symphysis has undergone very marked and peculiar specialisation consequent upon the failure of the two pubic bones ultimately to unite in the midventral line. In many cases the writer himself would be puzzled to give an unqualified determination of age unless the rest of the skeleton were at hand to confirm his interpretation and yet there are such possibilities for increasing the research value of a skeleton provided its approximate age can be discerned that it appears worth while to attempt to elucidate in detail the features presented by the human symphysis in order that age determination may be made with greater assurance. Of course I do not mean to lay inordinate value upon the symphysis as an age indicator. It is intended that eventually this portion of the skeleton shall take its appropriate place among the many skeletal age indicators which we have been able to recognise in working over the Reserve material. The field of investigation is so new and the features of skeletal metamorphosis so unfamiliar that essaying age determination upon a single skeleton or a single pelvis may prove an exceedingly discouraging task unless there be at hand a full presentation of the facts upon which the determination may be made. It is therefore my intention in the present paper to discuss the steps by which the well recognised oval outline of the symphysial face becomes built up, the age relationship of these successive phases and the modifications by which these age indications may be obscured.

In order to carry out this intention it is first necessary to give a brief résumé of the general mammalian characters of the area, and also of the features peculiar to Man.

Mammalian features of the symphysis pubis

In the reptilian pelvis as represented by Sphenodon, the pubis and ischium do not form a continuous symphysis but are separated from each other by an antero-posterior series of elements, namely the epipubis, the median ligament and the hypo-ischium. I have stated my opinion, based upon the work of Mehnert, that the single character of these elements is a secondary condition, and the elements are originally of a bilateral nature. The Monotreme pelvis is essentially reptilian in character and helps us very little. As in the reptiles pubis and ischium take about equal parts in forming the symphysis. The Marsupial pelvis is very different. There is vastly greater difference between the symphysial areas of the Marsupial and of the Monotreme than between those of the Marsupial and of the Placental mammal. The Marsupial symphysis may well be our starting point.

Fig. 1 shows the symphysial area of *Petaurus breviceps*, B 187, much enlarged. What I have called the median bar is clearly seen in this example. It expands above into the upper nodule and below into the triangular lower nodule through which it is continuous with the ischial epiphysis on each side. The median bar, the upper and lower nodules are homologues of the median ligament, the epipubis and the hypo-ischium respectively. This median bar extends for a certain distance between the symphysial faces as shown in fig. 3, *Dendrolagus inustus*, B 193. It is not always visible on the surface. Fig. 2, the upper symphysial area of *Macropus bennettii*, B 181, shows only the upper nodule from which a slender rod passes deeply down between the symphysial faces and represents the median bar. Evidently the upper and lower nodules are originally bilateral, the median bar imperfectly so. In fig. 4, *Phascolomys tasmaniensis*, B 601, the beginning of the lower nodule is well shown and it is obviously the continuation of the ischial epiphysis. At a later period in this animal the upper nodule and then the median bar would have developed, the elements of the two sides rapidly uniting. In adult life these elements all fuse with the pelvic halves binding them immovably together. The last traces of the several elements are in process of being lost in fig. 5, a young adult *Odocoileus virginianus*, B 633. In the Virginia Deer in fact the upper nodule rarely exists at all. One of the features which differentiates the symphysis of the Marsupial from that of the Monotreme most strikingly is the very small part taken by the ischium in its formation. There are differences in this respect among the several Eutherian orders but, with one notable exception, all Eutherian orders conform in a general way with the type of symphysial area found in a typical Marsupial like Petaurus. The exception which I desire to emphasise refers not to examples among the Rodents, Insectivores, Edentates, Cetacea, Sirenia and Pinnipedia which have vestigial or highly specialised symphyses, but to the Primates. This order shows still further reduction and finally entire elimination of the ischium from participation in the symphysis with a consequent reduction and loss of the lower nodule as a separate entity.

It becomes merged again into the linear epiphysis extending along the pubic arch. The symphyses of the great Anthropoids form a special link between human and other Primate symphyses for whereas in some the two halves of the pelvis finally fuse at the symphysis, in others this fails to occur and a typical human form of ununited symphysis results. In those specimens in which union takes place a median bar and an upper nodule are formed but no lower nodule appears. The condition is exemplified in Gorilla B 624 (fig. 6). This is really the key specimen to a proper understanding of the human form of symphysis.

Now I have affirmed the bilateral nature of all the three median symphysial elements, evidence for which is presented elsewhere (v). Upon the basis of this assumption one would expect to find bilateral vestiges of the three structures. These do occur in the human symphysis and are responsible for the upper extremity, the ventral rampart and for the lower extremity, which together complete the oval outline of the symphysial face. The dorsal margin is not epiphysial in nature but is formed directly from the pubis itself.

In my former work I discussed first of all the features of the human symphysis and later sought to explain the occurrence of its peculiar features by reference to comparative anatomy. In my general survey of the human symphysis I came across many curious divergences from the normal or rather from the modal type—divergences in point of structure and time relationship —which I was quite unable to explain at the moment. It became clear in my last contribution (VI) that many of these anomalies are unquestionably evidence of the relationship of the non-uniting human symphysis to the typical mammalian form through a type such as that figured in the Gorilla (fig. 6). With this assurance it is now possible to trace the development of the human type of symphysis and to group the individual specimens according as they approach or recede from the more characteristic mammalian (or Primate) conformation.

In this communication I propose therefore to present the facts from this new angle and to confirm or correct the statements which I have previously advanced from a study of the human symphysis alone.

Peculiarities of the human symphysis

In this brief summary of the mammalian symphysis we have seen that there are two distinct elements in the formation of the symphysial face. The dorsal margin and part of the adjoining surface (dorsal platform) are formed from the pubic bone itself. The upper extremity and ventral margin (rampart) are epiphysial in character. The surface adjacent to the ventral margin is formed, like the margin itself, from the epiphysial element which, as the median bar or disc, penetrates backward between the two symphysial faces. The lower extremity, like the upper nodule and the ventral rampart, is typically formed from the epiphysial series in continuity with the epiphysis of the ischial tuber. In the Primates, however, this lower nodule is lost early and the majority

of Primates therefore do not show it. The Gorilla symphysis (fig. 6) is a good illustration of this condition. In the event, which in higher Primates is most probable, of the epiphysial series being weakly defined, the lower extremity is not formed by a nodule but fashioned in an ill-defined manner from the pubic bone itself. It is essential to keep clearly in mind the derivation of the higher Primate symphysial face. The dorsal margin and platform and sometimes the lower extremity are formed directly from the pubis; the upper extremity and ventral margin and sometimes the lower extremity are derived from an extension of the epiphysial tongue coursing along the pubic arch from the tuber ischii.

The condition of pubic development in the White stock is so aberrant and retrogressive that it is with difficulty that one can discern the typically Primate features. I propose therefore to take up first of all the appearance of the symphysis in the Negro in which the Primate character is more plainly seen.

Since the description of the male Negro symphysis was written (in the spring of 1921) there have been many accessions to our skeletal collection and fortunately the new specimens fill the gaps formerly existing and clear up many debateable points. It was with some difficulty and hesitation that I originally defined the successive phases of Negro symphysial metamorphosis. Whereas the male White skeletons fell fairly well into line with the scheme finally adopted (1), the male Negroes were at first exceedingly troublesome. The main difficulty was in the order of formation of the extremities and of the ventral rampart. In the case of the male Whites I had been compelled to admit the irregularity in occurrence of the upper extremity (1, p. 307) together with the variability in distinctness of the lower extremity and in the manner of formation of the ventral rampart (1, p. 308). Nevertheless, leaving out of account the exact manner in which these several parts are developed, there is a succession in point of time for the definition of the symphysial outline and this succession may be usefully employed as an age indicator. The appearance of the Negro symphysis is much more difficult to evaluate, not because it is erratic, but because the whole description of symphysial metamorphosis was based in the first place upon the White stock. The Negro partakes to a somewhat greater extent of and certainly shows more plainly the more typical Primate features and it is these very Primate modifications of the modal mammalian symphysis which introduce a confusing element. While the Negro features were read in the light of those exhibited by the White stock and have been so described it became evident that much greater progress would be made in the interpretation of the Negro features if a survey of the mammalian orders were undertaken first of all. We now find ourselves with that information to hand and particularly with the very suggestive knowledge that among the giant Anthropoids there are two distinct types of symphysis, one in which fusion takes place about phase VII, whereas in the other the symphysis remains unfused throughout life exactly as in the human condition.

Now this differentiation of the Anthropoid symphysial metamorphosis into

two types, one partaking of the general mammalian character, the other clearly forming a link with the appearance of the human symphysis, indicates that we may be justified in looking for different types in the human symphysis itself and these have already been discussed in a very general manner. In my study of variations of the area I have mentioned that "as for any Stock-linked character in variations the evidence is not as yet very strong but there does seem to be some indication that the Negro-hybrid symphysis is apt to partake of a more typically Primate character" (VI, p. 422). It was necessary to wait for more material before making a categorical statement upon the subject and our greatest need was for material in the third decade of life. This addition of material has now been obtained and by its help we are enabled to derive a convincing demonstration of the essential truth of this statement.

An anthropoid strain in the Negro symphysis

In the immediate post-adolescent stage there is no obvious difference at the symphysis pubis distinguishing the Negro from the White. Phase I has been defined as having the following distinguishing characters. Symphysial surface rugged and traversed by horizontal ridges separated by well-marked grooves, the ridges in the Negro being, if anything, a little more uniform in size than in the White; no ossific (epiphysial) nodules fusing with the surface; no definite delimiting margin; no definition of extremities. Phase II is also characterised by subequal horizontal ridges but dorsally there is distinct evidence of osseous activity, for the grooves between the hinder ends of the ridges are becoming obliterated by a new finely-textured growth of bone. A dorsal delimiting margin is beginning to form and take the place of the more or less apparent dorsal outline present even at adolescence. The ventral part of the symphysial face becomes more sloping or bevelled, a curious feature which will repay further study. In some cases there appears at this stage a bony epiphysial nodule at the upper extremity of the symphysial face. There is no delimitation of extremities. These two phases carry us to the twenty-second year of life. It is immediately after this that the perplexing variations occur.

As an introduction to the interpretation of the more obscure features which we shall meet with immediately let us glance over the characters of the symphysial face in No. 366, a male Negro of twenty-two years (fig. 7). From this enlarged photograph one can see the growing dorsal margin and the dorsal platform developing alongside. The addition of bone to form this margin and the platform is very irregular. On the left side it is not thicker than 0·5 mm. On the right side the thickness is 6·5 mm. at the level of the upper nodule which is so clearly seen whereas at the lower end of the symphysis it is only 3·0 mm. The addition of this mass of bone naturally enhances the ventral bevel and where it exists it obliterates all sign of horizontal ridges and grooves. The ventral area of the surface shows a very finely honey-combed vascular surface upon which remnants of the ridges still remain. The question naturally

arises as to what is happening in the ventral part. I do not believe that any erosion has yet begun. There is no active destruction of bone but there is molecular disintegration of the ridges resulting from transformation of the surface. An upper nodule exists as yet only on the right side. It is plain that this nodule in itself does not define the upper symphysial extremity. That delimitation will appear later and the distinction between the nodule and the real upper extremity will then make itself obvious. No suggestion of the lower extremity is present and the symphysial face tends to follow down and fade out upon the margin of the sub-pubic arch as is the case in the Anthropoid. An upper nodule may of course never appear and the symphysial outline is developed equally well without it.

The upper nodule of bone on the right side of No. 366 may justly be compared with the median bar of Gorilla B 624 (fig. 6) of which it is the homologue and counterpart. Keeping this in mind we are ready to understand the condition present in No. 744, a male Negro of twenty-two years (figs. 8 and 9). The actual symphysial face is younger in this specimen than in the last. The dorsal margin has not yet developed and nothing but a mere outline is present, such as one would expect in phase II. The epiphysial upper nodule is already formed and fused so that it stands out in marked contrast to the ventral rampart and to the lower extremity which are both well developed. These are still, as it were, laid upon the surface of the pubic bone; they have not become a part of it as is the case with the upper nodule. Apart from the site of fusion of the ventral rampart and the lower nodule the horizontal ridges are still quite apparent. There is indeed nothing to indicate an age greater than twenty-two except the obtrusive epiphysial extensions, namely the ventral rampart and the lower nodule. Now this specimen presents two problems. The first is the meaning of the early appearance and vivid delineation of the rampart and the lower nodule; the second is the correct evaluation of the several features of the symphysis in relation to age. Should one, for example, depend upon the very obtrusive rampart as an indicator or should one rely upon the condition of the dorsal margin? In practice I find that these are the two problems which dog one's steps throughout this study of age characters of the symphysis. No better specimen than No. 744 could be presented for elucidation of these problems.

The ventral aspect of No. 744 shows well the thickness of bone laid down in the ventral rampart. Just below the upper nodule, at the point where the delimiting line veers suddenly outward toward the tubercle, the thickness of this new bone is 9·0 mm.; at the level of the lower extremity of the symphysis it is 6·0 mm. No bone has been deposited on the dorsal part of the surface consequently the bony thickening merely fills up the ventral bevel remaining from adolescent times. There is no doubt about the Primate character of the bone deposit in this specimen. We have here a median bar, albeit split into two ventral ramparts, even better developed than in the Gorilla B 624.

Naturally one does not expect to obtain often so striking an example as

No. 744, any more than one anticipates finding an Anthropoid so fortunately apposite as B 624. But having seen these bones one has no hesitation in interpreting the much more frequent condition of the human symphysis as exemplified by No. 860 of age twenty-three (fig. 10), a male Negro like the rest. The features characteristic of No. 744 are again apparent here but are not nearly so prominent. Even a specimen like this is comparatively rare in the White series, at least at so young an age, and would have been classed in my former work under the heading of a sporadic precocious attempt at rampart formation. So far as Man is concerned the interpretation is undoubtedly correct but clearly this precocious rampart formation is also a typical Primate feature undergoing retrogression though not so retrogressed here as in the majority of human specimens. It should be particularly noted that, in conformity with the age, the dorsal margin is barely beginning to form and there is no evidence at all of the lower extremity. The reader must not confuse the upper nodule present here with the later clearly defined upper extremity.

There are three factors responsible for the development of a margin round an articular surface and these come into play at very different periods of life. The first is the deposit of bone forming a basis or platform upon which the future plainly delimited surface will be fashioned. This factor is at work in the upper extremity of the symphysis at twenty-two. It is seen in No. 860. The second factor makes its presence felt at the site in question towards the end of the third decade. By it the rather shapeless mass of the upper nodule is remodelled into a clearly outlined upper extremity for the symphysis. The third factor does not appear at the symphysis until about forty-five. It is responsible for the definite rim which moulds up the margin into a somewhat sharp outline known to clinicians as lipping. In a later communication I shall have a good deal to say about this lipping which is not a pathological feature at all but an age feature of tolerable constancy. Of course the term pathological is open to considerable variety of interpretation; by it I refer to a physical change in the bone brought on and directly induced by disease.

In this specimen No. 860 one would not be so liable to a misjudgment of age through the appearance of the ventral rampart for it is obviously retrogressive and the lack of even an attempt at a lower extremity is perfectly evident. Nevertheless one cannot emphasise too strenuously or too frequently the necessity of pinning one's faith to the real pubis itself for indications of age, and not to any variable and retrogressive epiphysial structure. I realise very well the importance of this caution for the pitfall is one into which a careful observer may readily slip if he attempts to make a hasty decision.

A much more difficult specimen to interpret is No. 525 (fig. 11), a male Negro of twenty-two years. This has been described as accelerated in my previous work. The earlier discussion of this specimen (II, pp. 19–20) is quite significant and to this we must shortly return. At the moment however one recalls that a general acceleration of skeletal metamorphosis of about four years was accorded this individual. If the figure be examined attentively it

will be seen that the ventral rampart is simply a very retrogressive and consequently poorly defined example of the type of 744 and 860. The dorsal margin is not really formed nor is there any sign of the lower extremity. The upper nodule is indeed present as might be expected in any bone of this age but it is only the first of the three factors mentioned above which has so far been at work. The horizontal ridges are quite ill-defined; there is, one might say, a slovenliness though not a lethargy of bone formation but there is no real indication that the specimen is actually much older than his years.

We may now consider a specimen which exemplifies the last stage in the completion of symphysial outline so far as this "anthropoid" strain of human pelves is concerned. The specimen chosen is No. 791, a male Negro of twenty-eight years (fig. 12). Here we have a symphysial outline which in all essentials is completely developed. The dorsal margin and platform are clear. So is the lower extremity. The bony structure of the upper extremity and the ventral rampart are laid down although these features are not yet delimited in the finished manner characteristic of other parts of the outline. Further it is still obvious that both extremities and the ventral rampart have been developed from a new growth of bone laid down upon but not an integral part of the pubis itself. The ventral aspect indeed shows plainly a delimitation between these parts and the pubis. It also indicates the continuity of these parts through the lower extremity with the subpubic extension of the epiphysis of the ischial tuber. In my previous work No. 791 has been cited as an example of skeletal acceleration with contradictory features (II, p. 22) because, taking for the moment only the pubic characters, the symphysial outline is completed in specimens of about thirty-three years, yet this completion in No. 791 does not harmonise with the granular appearance of the symphysial face itself. The reason of the disharmony now becomes clear. It is the result of retention of an anthropoid strain relatively unusual in human symphyses.

Effect of the anthropoid strain upon phase sequence in the Negro

It is necessary now to consider modifications brought about by the anthropoid strain in the regular phase sequence of the Negro.

Among the fifty-two Negro male pelves of known age between seventeen and thirty-one years inclusive there are thirteen showing an undoubted anthropoid strain. This first makes its appearance at twenty-two years with the precocious (for Man) development of a ventral rampart. After thirty-one years the distinction between the anthropoid strain and the more typical human sequence becomes obliterated since the human sequence has by then caught up with the other type. The thirteen pelves in question are the following:

Age 22.	Nos. 525, 744.	Age 26.	Nos. 190, 809.
23.	„ 860.	28.	„ 791.
24.	„ 857.	29.	„ 568, 569.
25.	„ 458, 764 (VI. fig. 4).	30	„ 343.
		31.	„ 448.

Of these No. 525 shows about four years' acceleration and No. 764 about four years' retardation in symphysial appearance. Now the phase sequence typical for the male Negro has been previously defined but for convenience the leading features should be restated.

Phase I. Age –19. Typical adolescent ridge and furrow formation with no sign of margins and no ventral bevelling.

Phase II. Age 20–22. Foreshadowing of ventral bevelling with slight indication of dorsal margin.

Phase III. Age 22–24. Progressive obliteration of ridge and furrow system with increasing definition of dorsal margin and commencement of ventral rarefaction (bevelling).

Phase IV. Age 25–26. Completion of definite dorsal margin, rapid increase of ventral rarefaction and commencing delimitation of lower extremity.

Phase V. Age 27–29. Commencing formation of upper extremity with increasing definition of lower extremity and possibly sporadic attempts at formation of ventral rampart.

Phase VI. Age 30–33. Development and practical completion of ventral rampart with increasing definition of extremities.

Phase VII. Age 33–38. Changes in symphysial face and ventral aspect of pubis consequent upon diminishing activity, accompanied by bony outgrowths into pelvic attachments of tendons and ligaments.

Phase VIII. Age 39–45. Smoothness and inactivity of symphysial face and ventral aspect of pubis. Oval outline and extremities clearly defined but no "rim" formation or lipping.

Phase IX–X. Age 45– . Development of "rim" on symphysial face with lipping of dorsal and ventral margins. Erosion of and erratic, possibly pathological, osteophytic growth on symphysial face with breaking down of ventral margin.

For pelves of the anthropoid strain the second period, namely that during which the symphysial outline is built up (see IV, p. 63) is strangely jumbled and the phase sequence is actually inverted, phases IV, V, VI appearing in exactly the reverse order. It is this inversion which may be the cause of confusion in interpretation if the investigator is unwary.

A study of the pelves just enumerated shows the following features of phase sequence. At twenty-two the ventral rampart begins to form but not yet to fuse with the pubis. At twenty-three fusion of the rampart takes place. At twenty-four changes occur in the symphysial face itself and the upper epiphysial nodule begins to assume the character and outline of an upper extremity. These features continue to become more strongly marked during the twenty-fifth and twenty-sixth years during which time also the lower extremity makes its appearance. At twenty-eight fusion between the epiphysial structures and the true pubis is so thorough that there is commencing obliteration of the earmarks of the original anthropoid strain. This obscuration continues until thirty when it is almost fully developed. At thirty-one the ventral

margin becomes strictly delimited through the influence of the second factor in articular outline definition discussed on a previous page. Stating these features in terms of the phase sequence we find that phase VI begins at twenty-two, phase V at twenty-four and phase IV at about twenty-six. Phase VII follows at twenty-eight and phase VIII at about thirty. As a matter of fact these age relationships are not far from the probable age relationships in the giant Anthropoids although we cannot enter into a full discussion of this matter at the moment.

Comparing the statement of phase in the anthropoid strain with that typical of Man as enumerated above we find that phase III and phase IV, being defined by features of the pubis itself, occur in their normal order and at the regular time as in other human pelves. The dislocation in phase-age relationship is brought about by the retention of a comparatively well developed median bar (ventral rampart) and upper nodule. Reference to the key specimen Gorilla B 624 (fig. 6) will make this clear.

Certain anomalous features in the regular phase sequence as originally defined now begin to appear in their true light. For example, the troublesome manner in which the upper extremity sometimes becomes defined as soon as or even sooner than the lower extremity is obviously due to an "anthropoid" influence. The sporadic early appearance of the ventral rampart is explicable upon the same basis. These matters must receive further attention after we have investigated the more typically human series of Negro symphyses.

The regressive type of Negro symphysis

In the foregoing pages we have considered a type of symphysis showing distinctly a form of metamorphosis which is nearly related to and clearly a variant upon the anthropoid type. It is however inconceivable that so profound a modification as permanent separation of the pubic bones could occur without some marked concomitant changes discernible in human symphysial metamorphosis. I am therefore about to present the type of symphysis which illustrates most definitely the peculiar human features of this curious bony change. Of the fifty-two pelves at present under consideration twenty-nine may be classed as being typically human. But upon the macerated skeleton there is no gross symphysial difference between anthropoid and human types until the age of twenty-two years so we may rule out from the present group the ten pelves of an age less than this. The remaining nineteen are the following:

Phase III.	Age 22.	No. 366. Accelerated to 24.
		703. Accelerated to 24.
		765. Retarded to 19.
	23.	No. 506. Typical (II. fig. 11).
		782. Typical.
		792. Retarded to 19 (VI. figs. 10–11).
		850. Typical.
		862. Typical.
		874. Accelerated to 25.

Phase III.	Age 24.	No. 497. Retarded to 22.
		523. Retarded to 19.
		524. Typical (but with lower epiphysis (VI. figs. 12–13)).
		858. Retarded to 20.
	27.	No. 379. Retarded to 25.
Phases IV and V.	Age 28.	No. 474. Retarded to 25.
		658. Retarded to 24.
		778. Retarded to 25.
	29.	No. 259. Retarded to 26 (II. fig. 15).
		402. Retarded to 25 (II. fig. 14).

The original phase sequence was defined, it will be recalled, for male White pelves and no alterations were made for the Negro except such as seemed clearly indicated. Since the original observations were made we have added about two hundred skeletons to the collection and these have naturally rendered some modification for the Negro advisable although one would hesitate to make any dogmatic and precise statements as yet. One notes the small accelerations and retardations of a couple of years or so and may ignore them. No marked accelerations can occur among this list for it has been shown that such accelerations were due to the anthropoid strain. The striking feature of the list is the increasing number of retardations of several years duration, three or even four. The five year retardations have already been discussed in my former writings (II), but it is these smaller retardations, becoming rapidly more frequent until all symphyses of ages twenty-seven to twenty-nine are included, which arrest the attention and demand explanation. Phases III and V commence at the expected time; phase IV is delayed two years. There is no delay in phase VI since it is shortly after thirty years that this type of symphysis catches up on those of the anthropoid strain. As a matter of fact this series shows very well the delay characteristic of the human pubis in entering the second period of symphysial metamorphosis during which the actual outline is built up (IV, p. 63).

Concerning the precise manner in which the outline is developed it is unnecessary to enlarge. In formation of the upper extremity a special epiphysial bony nodule may or may not take part. There is no essential difference from the appearance of No. 525 or No. 860 (figs. 10, 11). The lower extremity is formed by delimitation largely on the pubic bone itself, and the ventral rampart by the linkage of independent bony nodules or by gradual accretion of new bone upon the eroded, bevelled ventral area. These processes have already been fully described and figured (I, pp. 306–308; II, p. 8). The reader is referred particularly to a discussion of variations in type of symphysial metamorphosis the accompanying figures of which are large and render more easy the interpretation of the more numerous illustrations in the body of the work (VI, pp. 410–413).

Negro symphyses of intermediate type.

It is possible that the preceding pages may have served to render still more obscure the problem of the symphysis. There is no mental tidying up without the use of "pigeon holes" and there can be no adequate final synthesis without a preliminary and searching analysis. I am therefore about to complete this analysis as far as we may carry it at the moment by presenting a series of pelves which defy assignment to either of the two groups so far considered. Of the forty-two Negro male pelves in question these number ten. The peculiar feature of these symphyses is that they invariably show some evidence of a rudimentary or spasmodically developing ventral rampart at an unusually early age for Man. This of course can have no other meaning than an origin from the anthropoid strain type of symphysis. Yet the vestiges of rampart are unrecognisable as such without previous knowledge of the first group which I have considered and figured in this communication. The sporadic occurrence of attempts at formation of a ventral rampart has been allowed for in my initial definition of phases and therefore it is possible to assign each symphysis to the phase-age scheme originally established. The complete list is the following:

Phase III.	Age 22.	No. 413.	Typical (VI. figs. 14–15).
Phase IV.		846.	Accelerated to 25.
Phase V.	Age 26.	No. 435.	Accelerated to 28.
		859.	Accelerated to 28.
	27.	No. 716.	Typical except for rampart vestige.
		802.	„ „ „ (II. fig. 13).
	28.	No. 855.	„ „ „
	29.	No. 563.	„ „ „
	30.	No. 326.	„ „ „
		598.	Retarded to 24.

In accordance with their acceleration No. 846 becomes classified in phase IV, and Nos. 435 and 859 in phase V.

Phase and age relationships of our Negro male symphyses of the third decade

From the analysis just made it is possible to interpret the appearance of symphyses characteristic of the third decade much more intelligently and accurately than upon the baldly sketched outline hitherto published. There are undoubtedly two well marked types of symphysis easily referable to the anthropoid and regressive human strains. In addition there are always some for which the precise assignment is not so simple. These are really degenerate members of the anthropoid strain which however have not become so regressive that their symphysial features can be appraised with ease as in the case of the other two groups. Of the forty-two pelves between twenty-two and thirty-one years under consideration, thirteen belong to the anthropoid strain, nineteen to the regressive group and the remaining ten to the intermediate type. Since

these last ten are derivatives of the first group it follows that the anthropoid and regressive types are almost evenly divided among our male Negroes.

Of course one might classify all the pelves as closer to or more remote from the typical Eutherian metamorphosis. In this case the anthropoid strain would come first, the intermediate type next and the regressive group last. Armed with a fairly comprehensive knowledge of the mammalian symphysis, it is much easier to classify and evaluate the several features of human symphysial metamorphosis to-day, than it was in the early stages of this survey. Nevertheless it is also fair to say that the original classification of the Negro symphyses was far more difficult than the arrangement of the Whites. As will be apparent later this difficulty in the Negroes did not really arise from a greater admixture of types but from a more abrupt differentiation of types which did not permit the slurring over of intermediate forms. Had one attempted in the first place to formulate a phase-age relationship from our male Negroes I am convinced that only bewilderment would have ensued. In the course of the next few pages I shall present evidence whereby the White symphyses may be analysed into the three divisions which we have been able to distinguish so clearly for the Negroes. Doubtless it will occur to the reader that with three different groups of symphyses each having a somewhat particular phase sequence and its own time relationship which is not steady for all three, there is little hope of arriving at a prediction of age for any individual pelvis. In this connection it must be remembered that, unless it is absolutely unavoidable, the symphysis should never be used alone; that the age prediction is at best an approximation; and that the most sanguine would not expect the prediction to be accurate to within less than two or three years if founded upon the entire skeleton, or to within less than five years if founded upon the pelvis alone.

In the tables recounting the several members of my three groups, I have given some data from which it can be deduced that the lee-way of five years for age estimation of the pelvis alone is ample for any skeleton of the third decade. It is also ample for any skeleton of less than fifty years but after that age the symphysis becomes distinctly less valuable as an age indicator.

The problem upon which we set out in this chapter was the synthesis of three types of symphysis into a phase-age scheme which does not involve too much detail to carry conveniently in mind when examining skeletons. Now this is precisely the problem upon which I set out several years ago and the scheme which I have restated in this communication is the final one decided upon for general purposes. If the reader use this he must in the first place, expect only an approximation correct within five years; secondly he must allow for the sporadic occurrence of a precocious (for Man) attempt at rampart formation; thirdly he must recognise the possible inversion of order of phases IV and V. With these points in mind it will be clear to the reader that my original phase-age sequence rests upon an extensive experience of all three types in both human stocks but more especially in the Whites. A con-

densed summary of the statements made in this paper may be arranged as follows, and from this it will be clear that my phase sequence is most closely bound to the regressive and intermediate groups, for the anthropoid strain was conjectured to be an anomaly in Man, a view essentially corroborated in the ensuing investigation of which this communication records a part.

Group	Commencement of phase in years			
	III	IV	V	VI
Male Negroes ...				
Anthropoid strain	22	26	24	22
Intermediate ...	22	25	26	30
Regressive ...	22	28	28	31

Groupings in the male White symphyses

In the male White series there are thirty-eight pelves of ages from twenty-two to thirty years inclusive. We have none of the age of thirty-one. These thirty-eight symphyses present no difficulty comparable to that of the Negro males. Twenty-five of them are at once allotted to the regressive group; nine show the anthropoid strain and four only belong to the intermediate type. So closely indeed do the intermediate symphyses simulate the true regressive characters that, when grouping the White pelves in my former communication (1, pp. 328–329), I made no special reference to them. The anthropoid strain did cause me greater difficulty and after much thought I decided to give them up for the time being, merely remarking that in spite of their obvious location in the table they show some aberrant features which I briefly defined. Three of the skeletons I withdrew temporarily from the series of known age pending further inquiry. These are Nos. 653 of the age of twenty-six, 310 and 618 both of the age of thirty. The remaining six I have called examples of the mingling of phases, and I state that "these notes (i.e. upon the phase mingling) are not found on specimens of more than twenty-nine years" (1, p. 329). This observation now comes to have an important and striking significance. It has been shown that shortly after thirty years the regressive type of human metamorphosis catches up on the type showing an anthropoid strain and that obliteration of distinctive features in grouping thereafter rapidly disappears. The strange and hitherto inexplicable absence of phase mingling thus obtains an adequate solution. It is true that after thirty-nine years retardation of metamorphosis becomes the striking feature and the phase characteristic of the age supervenes upon the previously incomplete stage. This is another question which must be reserved for future consideration but which also finds ready interpretation by reference to the facts of Eutherian symphysial metamorphosis.

It is unnecessary to dwell at present upon the particular features of the regressive group of White symphyses, but I do wish to make a careful distinction between the regressive group as a type of human metamorphosis and a *retrogressive* individual symphysis. The regressive group is an undoubted type and is the characteristic type of symphysial metamorphosis among Whites.

It is only in a somewhat less degree characteristic of the Negroes. Occasionally there is found within this group, and among Whites more frequently than among Negroes, a specimen in which, even in the early twenties, the bony conformation seems indolent. There are few, low or ill-defined horizontal ridges; the extremities, especially the upper, are poorly formed or not defined at all; the ventral rampart is permanently incomplete, irregularly formed or barely distinguishable from the rest of the symphysial face. Such a specimen is obviously even more degenerate than the regressive type and represents a stage still further removed from the general Eutherian form. This is a retrogressive or plainly degenerate symphysis. It is often but not necessarily associated with some anomaly in shape of surface contour of the symphysis and is particularly liable to mislead the observer who is not on the alert for its occurrence. I have figured it several times and examples are to be found in the female Negro No. 226 (VI, fig. 24) and in the male Whites No. 575 (I, fig. 17) and No. 317 (I, fig. 67). One curious peculiarity of this retrogressive form is that it occurs in the anthropoid strain as well as in the regressive group. Examples have been recorded in the male White No. 649 (I, fig. 61), and in the male Negro No. 525 (this paper, fig. 11). They must not be confounded with plain retardation such as is shown in No. 764 (VI, fig. 4). The occurrence of the retrogressive symphysis in both the anthropoid strain and the regressive group emphasises still further the real distinction between these two definite types of human symphysis, either of which may equally show degenerate forms.

Let us glance for a moment at the examples of anthropoid strain among male Whites in the third decade. They are the following:

Age 22. No. 256 (II + VI).
649 (II + V).
24. No. 667 (III + V).
25. No. 267 (IV + VI) (figs. 13, 14).
Age 26. No. 653 (New).
29. No. 436 (V and VI).
30. No. 247 (VIII).
310 (New).
618 (New).

In all these is an "admixture" of phase V or VI except in No. 247 which, as would be expected of the anthropoid strain at this age, is already quiescent and in phase VIII. The three marked "New" are now added to the list of pelves of known age for the first time. It is the unexpected and formerly inexplicable early appearance of the upper extremity (phase V) or ventral rampart (phase VI) which is the undoubted earmark of the anthropoid strain.

The intermediate type is represented in the third decade of our male Whites by four examples to which no particular reference has been made in my original classification (I, p. 328), but have all been figured, as stated below, for the purpose of identification at the proper juncture. This time has now arrived and the reader is referred to my former work for the details of their form. In each the anthropoid strain, though obscure, can now be identified. They do not constitute anomalies when properly interpreted but by their very indeterminate character indicate their "anthropoid" origin.

Age 26. No. 490 (I. fig. 20).
27. No. 491 (I. fig. 22).
614 (I. fig. 21).
30. No. 360 (I. fig. 33).

Relative frequency of the types in Whites and Negroes

In résumé there are, among eighty pelves of male Whites and Negroes between the ages of twenty-two and thirty-one inclusive, forty-four of the regressive group, twenty-two showing the anthropoid strain and fourteen of the intermediate type. These are distributed in the following manner:

	Anthropoid strain	Intermediate type	Regressive group	Total
White male ...	9	4	25	38
Negro male ...	13	10	19	42

On the face of these figures there is not enough evidence to conclude that the regressive group is much more characteristic of the White or that the Negro presents a greater tendency toward the anthropoid strain. It is perhaps significant however that examples of anthropoid strain are much better marked in individual specimens among Negroes. Had the original survey been made first upon our Negro material it is possible that the characteristics of the several phases and their precise age-relationships would have presented far greater difficulties in classification. And it is certainly true that these very plainly marked indications of anthropoid strain in Negroes provide the connecting link between human symphysial metamorphosis and the typical Eutherian sequence.

It is equally clear that the intermediate type of symphysis is the form which links up the regressive group with examples of the anthropoid strain and which renders certain the correct interpretation of the former.

Relation of the types to acceleration and retardation of phase

Several pitfalls, which present themselves in the course of age determination by reference to symphysial phase, have been discussed already, and indeed the one now to receive attention has had passing notice. It is this. Acceleration and retardation of metamorphosis at the symphysis are not terms corresponding to the anthropoid strain and to the regressive group respectively. Each type itself has a modal age relationship for the successive phases; these have been pointed out. But in each type there are certain specimens which leap in front of or lag behind the modal rate of progress in metamorphosis. No better examples could be used than Nos. 525 (fig. 11) and 764 (VI, fig. 4). Assuming that No. 744 (fig. 8) represents the modal appearance of the anthropoid strain in Negro symphyses of twenty-two years, then No. 525 is plainly accelerated. The ventral rampart is not only formed but is so fused with the pubic bone as to be practically indistinguishable from it. On the other hand No. 764, though of the age of twenty-five, has only an imperfectly formed ventral rampart. These two specimens deserve a little closer inspection.

No. 525 is distinctly anomalous in several respects. The surface is saddle-shaped on the left bone, biconvex on the right. The dorsal margin on both sides is complete in the upper half but almost lacking below. The symphysial surface itself has a waxy appearance upon which the ridges are present but are ill-defined. In other words the specimen is a retrogressive example of its type and the retrogressive appearance of the surface is associated, as so often happens, with anomaly in outline and in surface contour. The ventral rampart has grown irregularly on both right and left pubic bones, and is imperfectly separated from the rest of the surface. The upper extremity of both sides is completed, the lower extremity is not. The features of this specimen, on being analysed, are all indicative of the anthropoid strain but the appearances are by no means typical. For its age it is retrogressive as far as the anomalous outline and contour and the faintly marked ridges are concerned. It is accelerated however since fusion between rampart and pubis proper does not usually reach the stage here presented at the age of twenty-two years even in examples of the anthropoid strain. This skeleton has received notice in a former discussion (II, pp. 19–20); it comes from a man who died of pneumonia in our own wards at City Hospital. There is no doubt whatever about the correctness of the age record. Other bony features, the closure of the cranial sutures, the condition of the clavicles, and the vertebral epiphyses suggest an age of about twenty-six or rather more. This suggested age would be the one fitting the actual condition of the symphysis and hence the skeleton in general shows an advanced stage of bony metamorphosis for the real age of twenty-two years. In addition to the acceleration of skeletal metamorphosis in general, and so far as I know at present in no way related to this acceleration, the symphysis pubis belongs to the type which I have called the anthropoid strain.

No. 764 does not present nearly so difficult and involved a skeletal picture. Here there is no anomaly of outline or of surface contour. Further there is nothing of particular note in the general skeleton as the sternal epiphyses of the clavicles are not yet completely united and the epiphyses of the vertebrae and of the ribs are already fused. The ventral rampart is forming on the symphysial face but it has not reached the state of perfection shown in No. 744 which is three years younger. The upper and lower extremities are forming with the aid of nodules, the development of which from the horizontal ridges of the ventral bevel is very clearly seen. The essentially greater age of this specimen is disclosed however, by the fact that a dorsal margin and platform are almost completed by resolution of the horizontal ridges and furrows into a more or less uniform surface of a finely pitted vascular appearance. One might with justice ask why this specimen is not one of the intermediate type. The answer is far more easily given by demonstration than by description. One may define the symphyses of intermediate type as exhibiting a rudimentary or spasmodically developing rampart; this is so natural a description of the appearance that in the earlier work symphyses of intermediate type were thus classified. The case in point, No. 764, however shows a perfectly well developed rampart independent of the rest of the pubis and could be taken for a normal example of the anthropoid strain were it not for the discrepancy in

the stages of development of the rampart on the one hand and of the dorsal margin and platform on the other.

One might go on multiplying cases of acceleration and retardation but that is unnecessary; the two examples quoted give all the salient and crucial features to which attention should be drawn. Neither is it necessary to discuss features of acceleration and retardation in the more obviously human regressive type of metamorphosis; these have been dealt with on former occasions and have been copiously illustrated. There is, however, another point to which in conclusion we should devote a few moments, namely the relative importance of the several features of the symphysis as age indicators.

Relative importance of the several symphysial features as age indicators

In presenting the evidence in favour of an anthropoid strain in human symphyses I have emphasised the necessity of a correct evaluation of the various symphysial features as age indicators. I raised the question as to whether one should depend more upon the very obtrusive rampart as an indicator, or upon the condition of the much less striking dorsal margin and platform. It is well to be quite clear about this.

I have shown that the distinguishing features of the anthropoid strain are exhibited in the epiphysial remnants which together make up the ventral rampart and upper extremity, and also to a less extent, the lower extremity. These epiphysial remnants are especially well marked in the intermediate type and even in the regressive form of human symphysis although in these they are neither so pronounced nor so independent of the actual pubic bone itself. One might, and indeed would, classify the three types as stages of retrogression were it not that the first and third, at least, exhibit particular retrogressive forms which can be distinguished the one from the other. Now it follows that, in spite of their bolder character, the epiphysial remnants are less stable and less reliable as age indicators than the features of the pubic bone proper. I have given the phase-age relationships for the three types of metamorphosis in the foregoing pages and these tables show plainly how inadvisable it is to pin one's faith to these as age determinants without a very careful examination and strict discrimination between the types. Correspondingly elaborate precautions are not necessary in age estimation drawn from a study of the pubis itself since such variations do not occur.

The phases as defined earlier in this communication depend mainly for their elucidation upon features of the pubic bone and not of the epiphysial remnants although it is true these cannot be entirely ignored. Phases I, II, III depend upon the pubis alone. Phases IV, V and VI may or may not involve epiphysial formations as separate entities; both extremities may be developed without the appearance of a definite nodule and the ventral rampart may grow by simple accretion of bone upon the ventral bevel without the formation of bony bridges or other indications of a separate bony element. It must be carefully observed that in my definitions I do not lay stress upon the formation of bony nodules for extremities or rampart but rather upon the *delimitation* or increasing definition of these features. The essential principle

of age determination by means of the symphysis is therefore based upon the permanent characters of the pubic bone and not upon the epiphysial features which are variable in occurrence and in time relationship.

The figures which illustrate this paper are from photographic studies by Miss Helen F. Harvey. In view of the fact that Miss Harvey has now taken up other responsible duties befitting a woman's career it is becoming that I make some acknowledgment of the very unusual impetus which she has given to anatomical photography in its various aspects. Those who have seen her colour work and stereoscopic projection can never forget the debt of gratitude which students and teachers of anatomy owe to Miss Harvey for her ingenuity and skill in developing these processes to so fine a pitch of excellence and at the same time to so simple a technique that they must be used in all modern anatomical equipments of the next decade.

Summary

1. The human pubic symphysis presents a Eutherian metamorphosis in modified form as a result of the permanent separation of the two pubic bones.

2. Pubic metamorphosis in the giant Anthropoids is the connecting link between the human and the more typical Eutherian form. The epiphysial remnants of the human symphysis, namely ventral rampart, upper extremity and to a less and more variable extent the lower extremity, are the homologues of median bar and upper and lower nodules of typical Eutherian metamorphosis.

3. Among human symphyses, both White and Negro, there exist two well defined types of metamorphosis. The first has the epiphysial remnants obtrusively developed with consequent modification and even inversion of the phase-age relationship as originally enunciated. The second shows little or no independent epiphysial formation and is the modal type in both human stocks. The first of these types is clearly related to one form of metamorphosis as shown in the giant Anthropoids and therefore is called the anthropoid strain. The second is named the regressive type of human metamorphosis. Between these two modes there is an intermediate type of metamorphosis which serves to link the other two.

4. The three types occur in Whites as in Negroes but are more strikingly distinguished in the latter. There is no great difference in relative frequency.

5. Examples of both the anthropoid strain and the regressive type may be accelerated or retarded in time relationship and such examples differ in their exact features according to the type to which they belong.

In addition actual retrogressive examples of each type occur; these often present anomalies of outline or of surface contour in addition to the retrogressive features of the symphysial face.

6. In estimating age by the symphysis one must be cautious in evaluation of the several symphysial features, those of the pubic bone itself being much more reliable than the various epiphysial remnants. If the type is clearly distinguished however these remnants are of distinct help in coming to a correct conclusion.

Fig. 1. Symphysial area of young adult *Petaurus breviceps*, B 187, W.R.U., ventral aspect × 6·5. Note the median bar with club-shaped upper and triangular lower extremities (nodules).

Fig. 2. Symphysial area (upper part) of young adult *Macropus bennettii*, B 181, W.R.U., ventral aspect × 2. Observe well defined upper nodule. The median bar exists merely as a median disc between the symphysial faces.

Fig. 3

Fig. 4

Fig. 3. Symphysial faces of young adult *Dendrolagus inustus*, B 193, W.R.U., ×2. The left symphysial face is devoid of the epiphysial structures which are united by as yet non-osseous tissue to the right symphysial face. The small upper nodule is obscured by the ligamentous base for the "marsupial bone." The median bar stands out clearly and the tongue which projects between the symphysial faces is easily recognised. The lower nodule unites the ischial epiphyses of the two sides and hence in this specimen the left epiphysis is united to the right one on the right of the illustration.

Fig. 4. Symphysial area of young *Phascolomys tasmaniensis*, B 601, W.R.U., ventral aspect ×2. The lower nodule is the first of the median structures to ossify.

Fig. 5. Symphysial area of young adult *Odocoileus virginianus*, B 633, W.R.U., ventral aspect × $\frac{4}{3}$.

Fig. 4. Symphysial area of young *Phascolomys tasmaniensis*, B 601, W.R.U., ventral aspect × 2. The lower nodule is the first of the median structures to ossify.

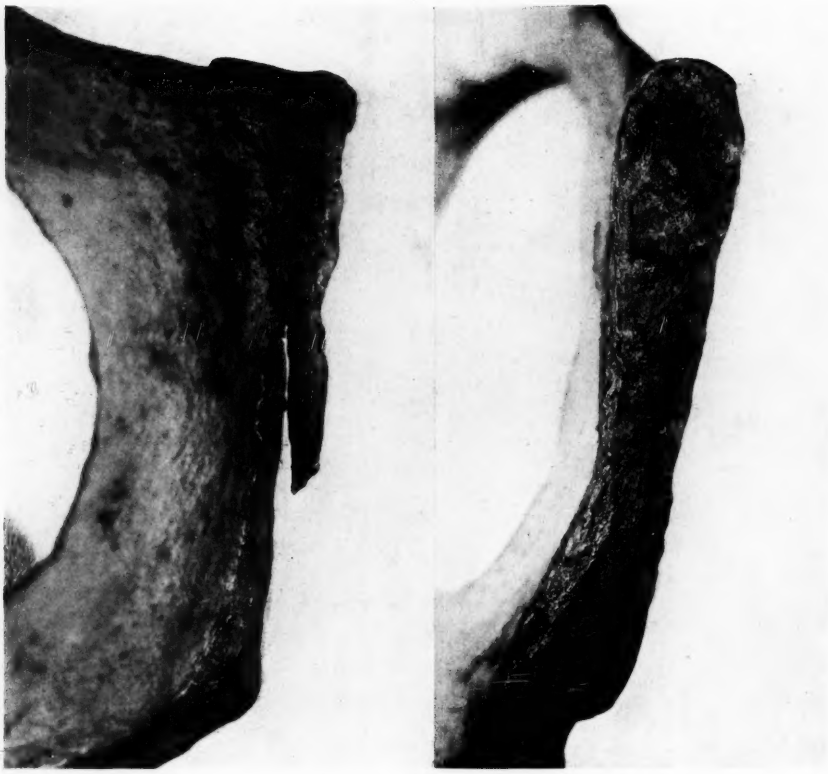


Fig. 6. Symphysial area of young adult *Gorilla gorilla* (Wyman), B 624, W.R.U., ventral aspect × ¾. The left pubis is shown in face, the right in ventral aspect. Note the median bar with expanded upper nodule. There is no lower nodule, the median bar (broken) merely tailing off below.

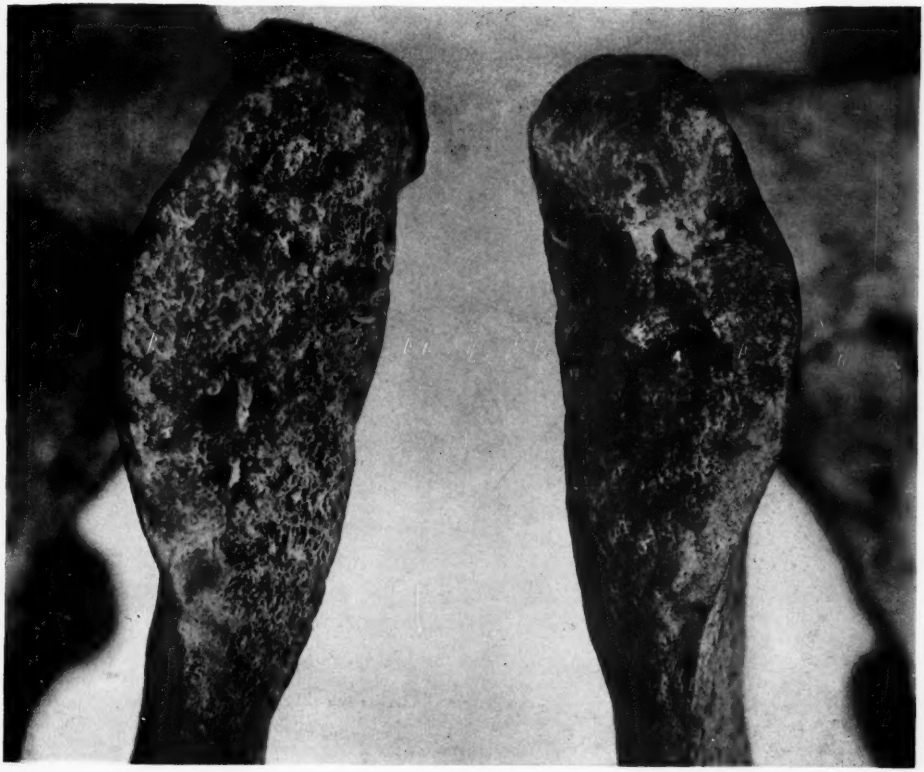


Fig. 7. No. 366, W.R.U., Negro, male, age 22. Symphysial faces × 2. Note the developing dorsal margin and adjacent "platform." The right side possesses an upper epiphysis or nodule of considerable development. This striking feature is absent from the left side. The ventral area (towards centre of illustration) shows a bevelled, finely honey-combed, vascular surface on which, especially on the left, remnants of horizontal ridges can be seen.

Fig. 8. No. 744, W.R.U., Negro, male, age 22. Symphysial faces × 2. There is here no sign of the dorsal margin or platform. The epiphysial upper nodule, ventral rampart and lower extremity (nodule) are well developed but as yet appear to be lying on the actual pubic face.

Fig. 9. No. 744 (compare Pl. VI, fig. 8). Ventral aspect of symphysis. Note the continuity of the epiphysial structures of the pubis with the epiphysis of the sub-pubic arch.

Fig. 10. No. 860, W.R.U., Negro, male, age 23. Symphysial faces ×2. On the horizontal ridges near the dorsal margin the transformation into a platform is beginning. Upper nodule, ventral rampart and lower nodule are present as in Pl. V. fig. 7, but much less plainly seen.

Fig. 11. No. 525, W.R.U., Negro, male, age 22. Symphysial faces × 2. On the horizontal ridges near the dorsal margin transformation of texture is commencing (cf. Pl. VIII, fig. 10). The ventral rampart and upper nodule are simply retrogressive and poorly defined examples of the type of Nos. 744 and 860. There is no lower extremity.

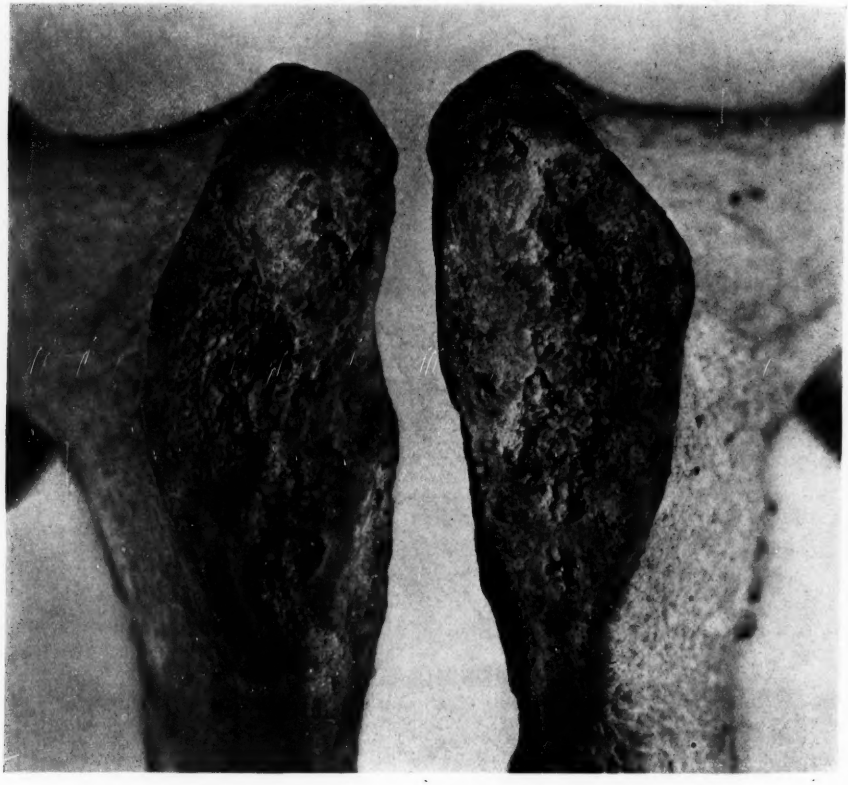


Fig. 12. No. 791, W.R.U., Negro, male, age 28. Symphysial faces × 2. This is late stage of the anthropoid strain just before final obscuration through fusion of the rampart with the pubic bone itself.

Fig. 13. No. 267, W.R.U., White, male, age 25. Symphysial faces × 2. This is an example of the anthropoid strain well marked for the White stock. It should be compared with Pl. VI, fig. 8 and Pl. VIII, fig. 10. Note the developing dorsal platform and the obtrusive ventral rampart with commencing definition of upper and lower extremities.

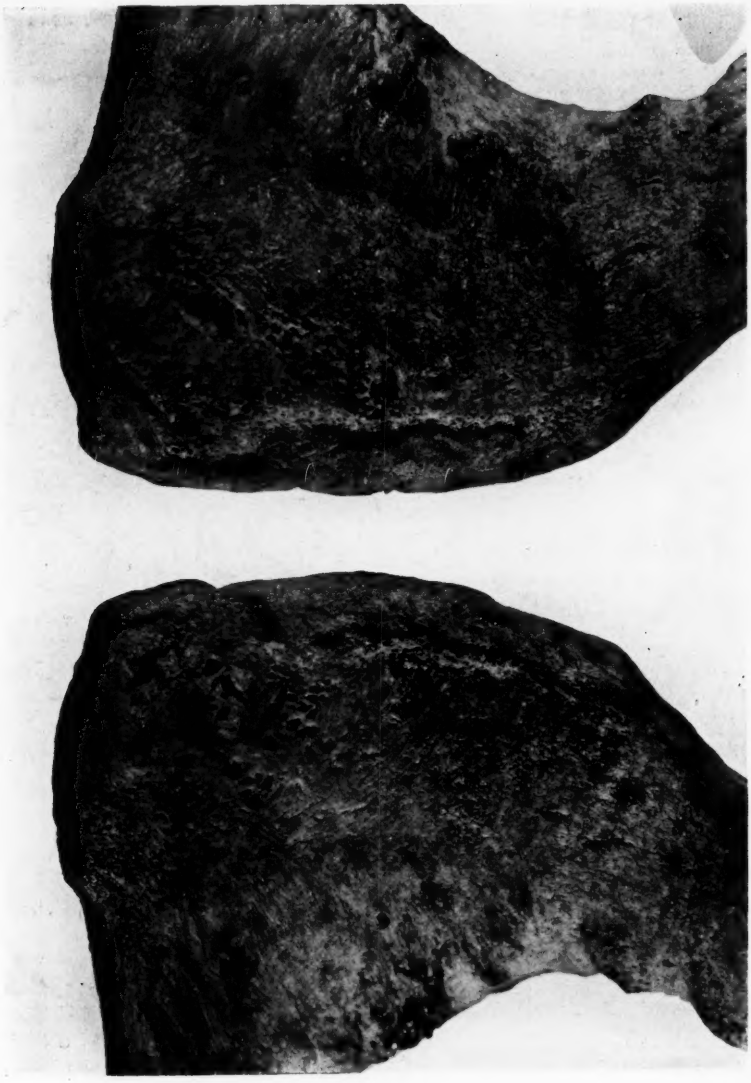


Fig. 14. No. 267, W.R.U., White, male, age 25. Ventral aspect of symphysis × 2. This and Pl. XI, fig. 13 are companions. Note the amount of bone belonging to the ventral rampart. Compare Pl. VII, fig. 9.